Appendix A

MALIBU LAGOON RESTORATION AND ENHANCEMENT PLAN

Prepared for

Coastal Conservancy
California State Coastal Conservancy

California State Department of Parks and Recreation

Prepared by: Moffatt & Nichol

In Association With: Heal the Bay

June 17, 2005 M&N File: 5381

FINAL MALIBU LAGOON RESTORATION AND ENHANCEMENT PLAN

Prepared for the:

California State Coastal Conservancy &

California State Department of Parks and Recreation

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EXECUTIVE SUMMARY

This Malibu Lagoon Restoration and Enhancement Plan presents detailed information to implement and monitor the preferred restoration alternative. The preferred alternative is Alternative 1.5, as specified in the Malibu Lagoon Feasibility Study Final Alternatives Analysis. Implementation details are provided in the form of plans for water management, habitat management, access, and monitoring to facilitate implementation of the monitoring program and subsequent environmental review and permitting. This document is intended to serve as a "living" document that is regularly updated as monitoring, planning and phased implementation proceed and new information is generated. It may be continually updated into perpetuity as monitoring and adaptive management occur.

Significant impairments currently exist at the lagoon primarily due to uncontrolled inflow of water from outside of its boundaries contributing pollutants and nutrients to the system, and poor circulation within its boundaries. The water management plan outlines restoration measures intended to control local outside inputs, such as storm drainage from the parking lot and irrigation from perimeter areas, as well as promote circulation of water within the lagoon. Storm drainage is to be managed by increasing percolation and drainage away from the lagoon. Measures include sloping the parking lot away from the lagoon to drain toward Pacific Coast Highway, using permeable pavement at the parking lot and entrance roads and vegetated swales along the parking lot perimeter. It may also be possible to divert and treat runoff by connecting to the City of Malibu storm drain force main to be installed in the near future. Circulation will be enhanced by reconfiguring the west lagoon to promote maximum tidal circulation during open conditions and maximize wind driven circulation during closed conditions. Circulation will be assessed by continuously monitoring and evaluating water movement within the lagoon to identify needed adaptive management improvements. Open and closed lagoon conditions are addressed, and the use of continuously monitoring gauges is specified. The plan includes performance criteria and adaptive management options so the plan can be revised if needed to ensure long-term restoration integrity and success.

Malibu Lagoon also experiences degraded habitat and invasion by non-native species due to anthropogenic disturbance and encroachment on the sensitive ecosystem of plants and animals. A Habitat Plan is provided specifying implementation practices and maintenance requirements for enhancement and management of the restored ecosystem. The plan defines vegetative communities that will be established and/or enhanced as part of the restoration process. Details are provided for slopes and drainage, topsoil salvage and management, planting and establishment, and maintenance for short- and long-term conditions. The plan utilizes an adaptive management framework to ensure long-term restoration integrity and success.

A Public Access, Education and Interpretation Plan is provided including a list of access options and creative ideas for implementation and management to enhance the educational and recreational user experience as determined from stakeholder input. The plan specifies a perimeter access plan at grade along the western edge of the western arms at the location of the existing

vehicle access route. Multiple interpretive nodes and areas suitable for educational programs are identified, and multiple length interpretive loops are provided to allow for a variation of docent led activities with exposure to multiple habitat types. A significant element of the plan is the relocated parking area, moved back and elevated to a position along the Pacific Coast Highway to be acoustically and visually buffered by a proposed extension of the "Adamson wall." Amenities of the access plan consist of a non-intrusion platform near the parking lot and Pacific Coast Highway, a view and access dock at the Adamson House, and a combination viewing and interpretive area called the "thick wall and duck blind" near the southwest perimeter to enable passive interaction without disturbance.

A detailed monitoring plan is provided setting out a program of field observations and monitoring to be undertaken prior to, during and following implementation. Specific monitoring tasks and decision-points are specified to feed into an adaptive management framework to ensure long-term restoration integrity and success. The Monitoring Plan will be used to assess floral and faunal assemblages, protect existing habitat, minimize impacts during restoration activities and document resource changes for application in future adaptive management programs. To achieve these objectives, the Monitoring Plan includes provisions for monitoring physical, chemical, and biological components. Required monitoring equipment, manpower, costs and schedules are provided in matrices at the end of this report.

Future tasks to be completed for restoration include monitoring, environmental review, permitting, final restoration design and phased restoration implementation. Specific stages consist of:

- Pre-restoration monitoring;
- Environmental review that will include additional data collection (includes public comments and hearings);
- Permitting by appropriate resource agencies (includes public comments);
- Final design for the restoration program that will likely include additional data collection and analyses;
- Phased restoration implementation; and
- On-going monitoring and adaptive management activities.

1.0 INTRODUCTION

Southern California has lost approximately 95% of its historic coastal wetlands. Previously viewed as poor quality habitats, the ecological importance of coastal estuaries and wetlands has recently been recognized. The highly urban setting of Southern California significantly limits coastal wetland creation, restoration and enhancement opportunities and Malibu Lagoon represents a unique opportunity to restore a valuable coastal wetland. The Malibu Lagoon Restoration and Enhancement Plan presents a comprehensive approach to restore and enhance the ecological structure and function of Malibu Lagoon, as well as to enhance the visitor's experience through improvements to access and interpretation. This plan is the result of two years of planning, design and evaluation and represents ecological solutions for this unique and valuable ecosystem. The Lagoon Technical Advisory Committee, California State Department of Parks and Recreation (State Parks), State Coastal Conservancy, and Lagoon Restoration Working Group have worked together to design a restoration alternative to restore the biological and physical functions to the lagoon while minimizing impacts to the existing system. Details of the restoration are described in this Restoration and Enhancement Plan that includes plans for management of water, habitat, and access, as well as a comprehensive monitoring plan.

1.1 BACKGROUND

Malibu Lagoon is a 31-acre shallow water embayment occurring at the terminus of the Malibu Creek Watershed, the second largest watershed draining into Santa Monica Bay. Malibu Lagoon empties into the Pacific Ocean at world famous Malibu Surfrider Beach. World renowned as a surfing and recreational destination, Surfrider Beach receives approximately 1.5 million visitors every year.

Anthropogenic activities have significantly altered the physical configuration of Malibu Lagoon. The existing lagoon is only a very small portion of its historic area. Urban encroachment has occurred on all sides. The Pacific Coast Highway (PCH) Bridge has dissected and constricted the lagoon surface area, and a significant portion of the once low-lying tidally influenced areas near the mouth of the Malibu Creek were filled in the 1940's and 50's.. By the late 1970's the site was completely filled and housed two baseball fields. Urbanization upstream in the Malibu Creek Watershed has increased the volume of water transported into the lagoon and urban pollution has significantly diminished the quality of that water through inputs of nutrients, sediments, and pollutants.

In 1983, the California Department of Parks and Recreation initiated a restoration of the lagoon. The restoration involved the excavation of three distinct channels (designated as A, B and C Channels) in the western portion of the lagoon, oriented perpendicular to the natural flow path of the Creek as shown in Figure 1. The channels were seeded with salt marsh plants and series of boardwalks were created to allow access by the public. In 1996, the California Department of Transportation (Caltrans) funded a successful restoration program to mitigate for impacts incurred during the Malibu Lagoon Bridge Replacement Project. Specific restoration measures, coordinated by the Resource Conservation District of the Santa Monica Mountains and (State Parks, included the very successful tidewater goby habitat enhancement project and the

Final Malibu Lagoon Restoration and Enhancement Plan	Existing Lagoon Conditions	**Figure 1**

revegetation of areas disturbed by construction activities with native species, including extensive removal of non-natives.

Despite these restoration efforts, the ecosystem of Malibu Lagoon remains degraded and in the late 1990's the California State Coastal Conservancy funded a study by UCLA (Ambrose and Orme 2000) to: 1) identify impacts to the ecological health and water quality in the lower creek and lagoon ecosystems and 2) provide recommendations on how to best manage these impacts. The study produced three categories of recommendations: 1) the installation of best management practices (BMPs) to improve water quality; 2) the creation of treatment wetlands to enhance the water quality of stormwater runoff; and 3) restoration of existing wetland habitat to enhance their ecological functioning.

Following a year long facilitation process, the restoration of the existing lagoon area and small parcel on the east side of the creek adjacent to the Adamson House was identified as the highest priority Short Term project by the Malibu Lagoon Task Force.

The restoration goals for Malibu Lagoon as identified by the Malibu Lagoon Task Force consist of:

- Salt Marsh Enhancement at Site A1 (West Arms)
    - Increase tidal flushing
    - Improve water circulation
    - Increase holding capacity
    - Reduce predator encroachment

- East Lagoon Restoration at Site A4 (Adjacent to Adamson House)
    - Regrade to restore typical salt marsh hydrology
    - Create nesting island for least terns and Snowy Plovers
    - Create channel connections to the lagoon

Based on the results of the Final Alternatives Analysis for the Malibu Lagoon Restoration Feasibility Study, the Lagoon Technical Advisory Committee, State Parks, and the State Coastal Conservancy, with substantial input from the Lagoon Restoration Working Group, recommend Alternative 1.5, the Modified Restore and Enhance Alternative shown in Figure 2, as the preferred restoration design for Malibu Lagoon. This restoration alternative is expected to most readily achieve the goals of restoration while introducing the least amount of impact to the existing lagoon ecosystem. Restoration efforts may be performed in succinct stages to minimize impacts to the existing wetland habitat and to provide refuge for species displaced by construction activities. A phased restoration implementation and long-term adaptive management approach will be implemented to maximize the ecosystem benefits of this project.

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Final Malibu Lagoon Restoration and Enhancement Plan	Alternative 1.5 Concept Plan	**Figure 2**

Details of Alternative 1.5 and how this design is best suited to meet the goals of the restoration program are available in the Malibu Lagoon Restoration Feasibility Study Final Alternatives Analysis. This document is available online at http://www.healthebay.org/currentissues/mlhep/default.asp. Major components of this design are described below.

Parking Lot and Staging Lawn

The existing parking lot will be relocated to the north and west to be adjacent to PCH, the current parking lot entrance from PCH and Cross Creek Road, and the current western property line. The new parking lot and staging area will be created with runoff treatment controls, including permeable pavement or other similar substances, appropriate native vegetation, and will include a staging area to enhance existing educational and recreational uses of the site. The new parking lot will maximize the use of Best Management Practices (BMP) to minimize or eliminate runoff to enhance water quality in the Lagoon. The current number of parking spaces will remain and new interpretative displays and panels will be installed.

Main Channel

The Main Channel will remain substantially "as is." The western edge of the main lagoon at the interface with the western arms complex will be reconfigured in the form of a naturalized slope to provide a degree of separation between the main lagoon and west channel system. All efforts should be made to allow the barrier berm to open and close naturally. Driving across the berm should be minimized and it is recommended that management of a section of the lagoon side of the berm be maintained to protect avian species from anthropogenic impacts during closed conditions.

East (A4)

The existing boat house channel will be deepened and recontoured to create a new avian island along the eastern bank of the Adamson House grounds. This work is expected to have a minimum impact on the existing habitat, will create additional mudflat habitat and promote additional water circulation around the new island.

West Lagoon Complex

A new channel will be created along the southern edge of the west lagoon to create a single main entrance and exit for water conveyed into and out of the west lagoon. This channel may be optimized to overlie the existing "C" channel to minimize the impact to existing habitat and will be designed to enable a future connection to the "golf course" parcel located adjacent and to the west of the lagoon. A naturalized slope separating the main channel from the west channel, with minimum elevation change, will be created using lagoon materials displaced by dredging of the new main west channel and those that currently exist along this edge. The main west channel will possess a natural dendritic planform to maximize tidally-influenced water inundation to the west channel and its fingers. Isolated bird islands will be created to provide refuge for foraging and/or loafing birds. These islands will be optimized to maximize the use of the existing wetland habitat to minimize impacts to the existing system.

1.2 PURPOSE OF THIS DOCUMENT

The Restoration and Enhancement plan is developed specific to the preferred alternative to facilitate the initiation of monitoring, environmental review, permitting, final restoration design and phased restoration implementation. These specific stages will include:

- Pre-restoration monitoring;
- Environmental review that will include additional data collection (includes public comments and hearings);
- Permitting by appropriate resource agencies and responsible permitting agencies (includes public comments);
- Final design for the restoration program that will likely include additional data collection and analyses;
- Phased restoration implementation; and
- On-going monitoring.

Under a Proposition 13 grant from the State Water Resources Control Board, the State Coastal Conservancy has secured funds to complete the initial stages of the project. The Resource Conservation District of the Santa Monica Mountains has been contracted to administer the project on behalf of State Parks, and will continue to work closely with the State Coastal Conservancy, the Lagoon Technical Advisory Committee and the Lagoon Restoration Working Group. The restoration design will evolve and be further optimized as it proceeds through the subsequent stages of permitting, final design, and phased implementation. The public will have opportunities to comment and provide input throughout the permitting and restoration design optimization stages.

To efficiently achieve the stages listed above, the Malibu Lagoon Restoration and Enhancement Plan specifies the following components:

1. Water Management Plan
   - A water management plan is specified to manage drainage from the parking lot and public use areas to restored habitat areas. It includes Best Management Practices to enhance water quality in the lagoon.
   - Circulation of water within the lagoon will be closely monitored and evaluated. The Water Management Plan includes performance criteria and adaptive management options so the plan can be revised if needed to ensure long-term restoration integrity and success.
2. Habitat Plan - A detailed habitat enhancement and management plan specifies implementation practices and maintenance requirements. The Habitat Plan defines vegetative communities that will be established or enhanced as part of the restoration process. This plan addresses the establishment or enhancement of habitat for rare, endangered and regionally uncommon plants and animals that are appropriate for this site

and uses an adaptive management framework to ensure long-term restoration integrity and success.

3. Access, Education, and Interpretation Plan - A public access, education and interpretation plan is provided including a list of access options and creative ideas for implementation and management to enhance the educational and recreational user experience. The access plan considers stakeholder input, educational and recreational users of the site.

4. Monitoring Plan - A detailed monitoring plan is provided setting out a program of field observations and monitoring to be undertaken prior to, during and following implementation. Specific monitoring tasks and decision-points are specified to feed into an adaptive management framework to ensure long-term restoration integrity and success. The Monitoring Plan includes:

   - Habitat – flora and fauna;
   - Water quality – during both open and closed conditions;
   - Sediment Quality – sampling of grain size; and
   - Bathymetry – Lagoon topography.

2.0 WATER MANAGEMENT PLAN

The objectives of the water management plan are to eliminate all point source discharges to the lagoon to maximize lagoon water quality, and to improve and maintain circulation within the lagoon under all conditions. Direct surface discharges to the lagoon can occur from storm water and from irrigation. Circulation is influenced by hydraulic conditions at the lagoon. These processes are discussed below.

As this project site is high-profile, it is an opportunity to provide a widely-viewed water quality demonstration project for the public. The experience and information gained from this demonstration project site (i.e., in the form of tours and available educational materials) can be used by the fields of education, public works, restoration, and others for improvement of water quality at other locations.

2.1 STORM WATER MANAGEMENT

In the wet season, storm water runs off the existing surface of the parking lot, entry road, turf area and kiosk, and eventually flows toward the lagoon, as shown in Figure 3. Storm water can be better managed to minimize or even eliminate direct runoff to the lagoon. Several suggestions to improve storm water management are provided below. For each item below, water quality benefits are increased percolation of storm drainage and possibly more efficient conveyance to a drainage system to the future City treatment plant, both resulting in less direct runoff to the lagoon. Less runoff will reduce the inputs of pollutants to the lagoon such as metals, bacteria, total petroleum hydrocarbons, nutrients, oils and grease, and possibly others thereby maintaining higher lagoon water quality than currently exists.

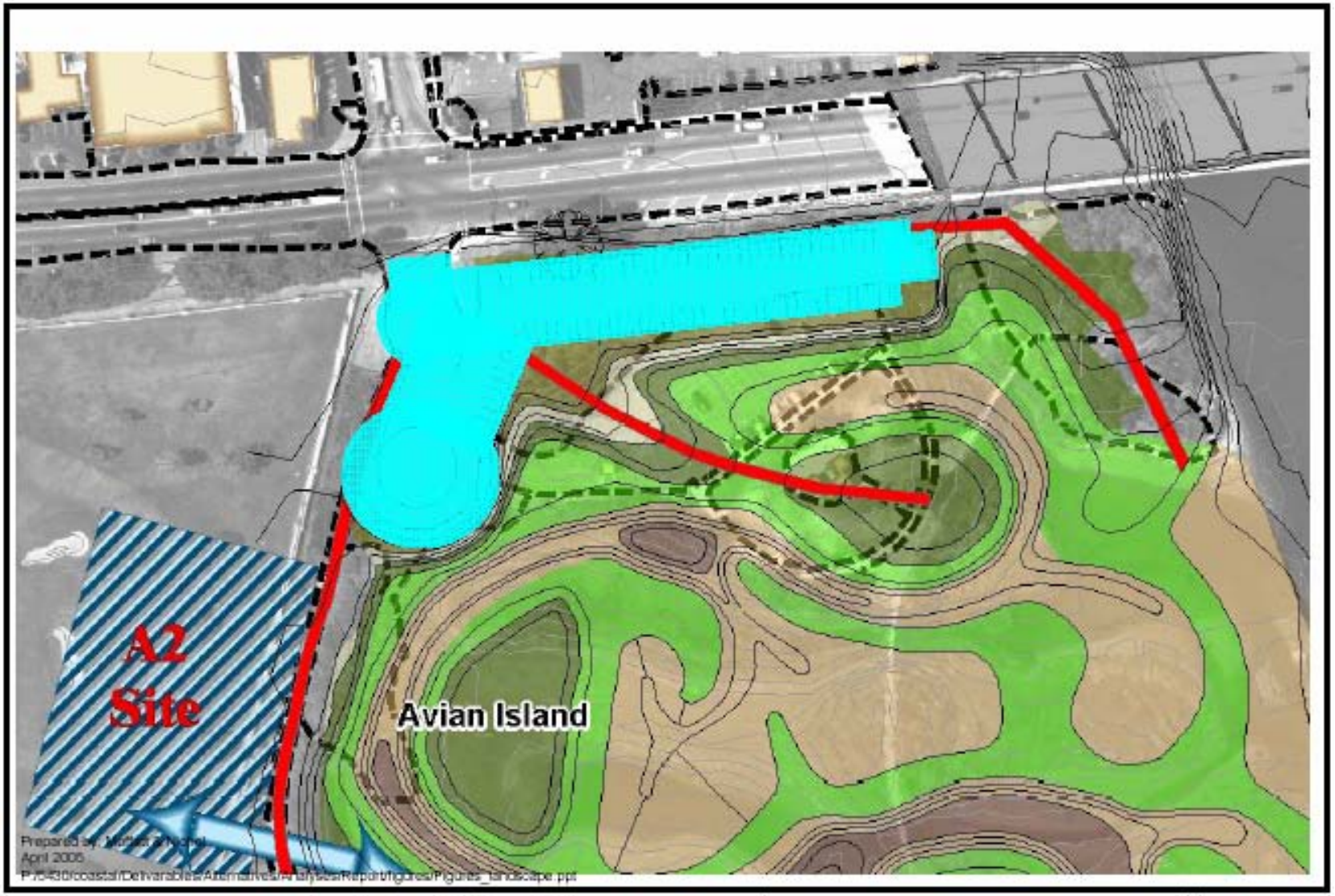
2.1.1 Increased Permeable Surfaces

Permeable Pavement

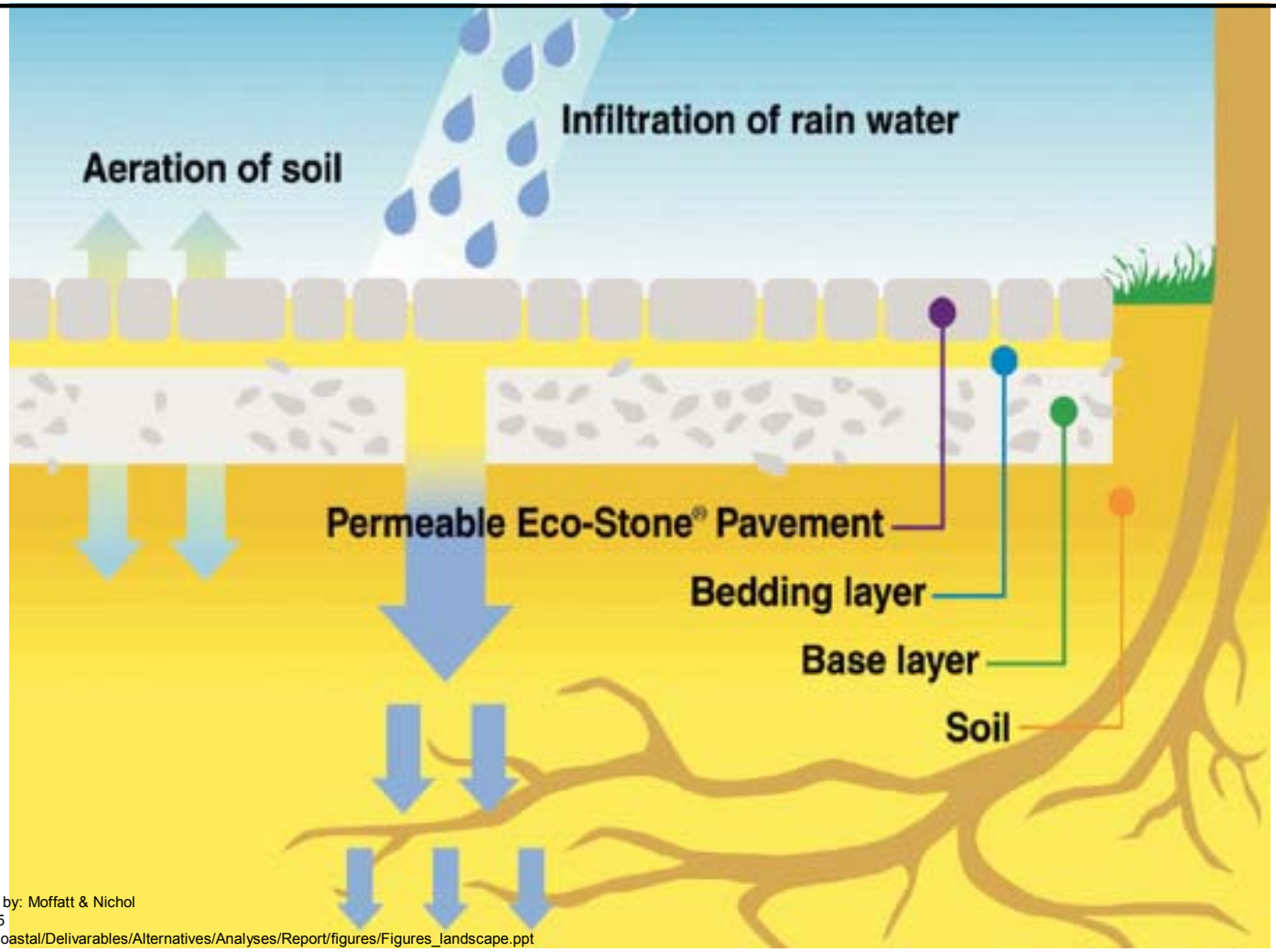
Permeable pavement is available for constructing a parking lot and entrance road that are more permeable than the asphalt and concrete that presently exist at the site. Figure 4 shows the recommended location for permeable pavement. Materials used to create this feature are permeable interlocking concrete pavements. These surfaces are constructed of individual paver stones interlocked, and shaped to provide gaps to allow infiltration between the stones into a porous base.

The paver stones are placed over an 8 inch thick base layer of ½ inch crushed aggregate, under a 1 inch thick setting bed layer of 3/8 inch crushed rock chips. The crushed rock chips are also poured into the gaps between paving stones after the stones are laid. Storm water infiltrates through the gaps in the surface layer, and percolates through the coarse bedding material into the underlying soil and eventually the groundwater zone as shown generically in Figure 5, and for site-specific conditions in Figure 6.

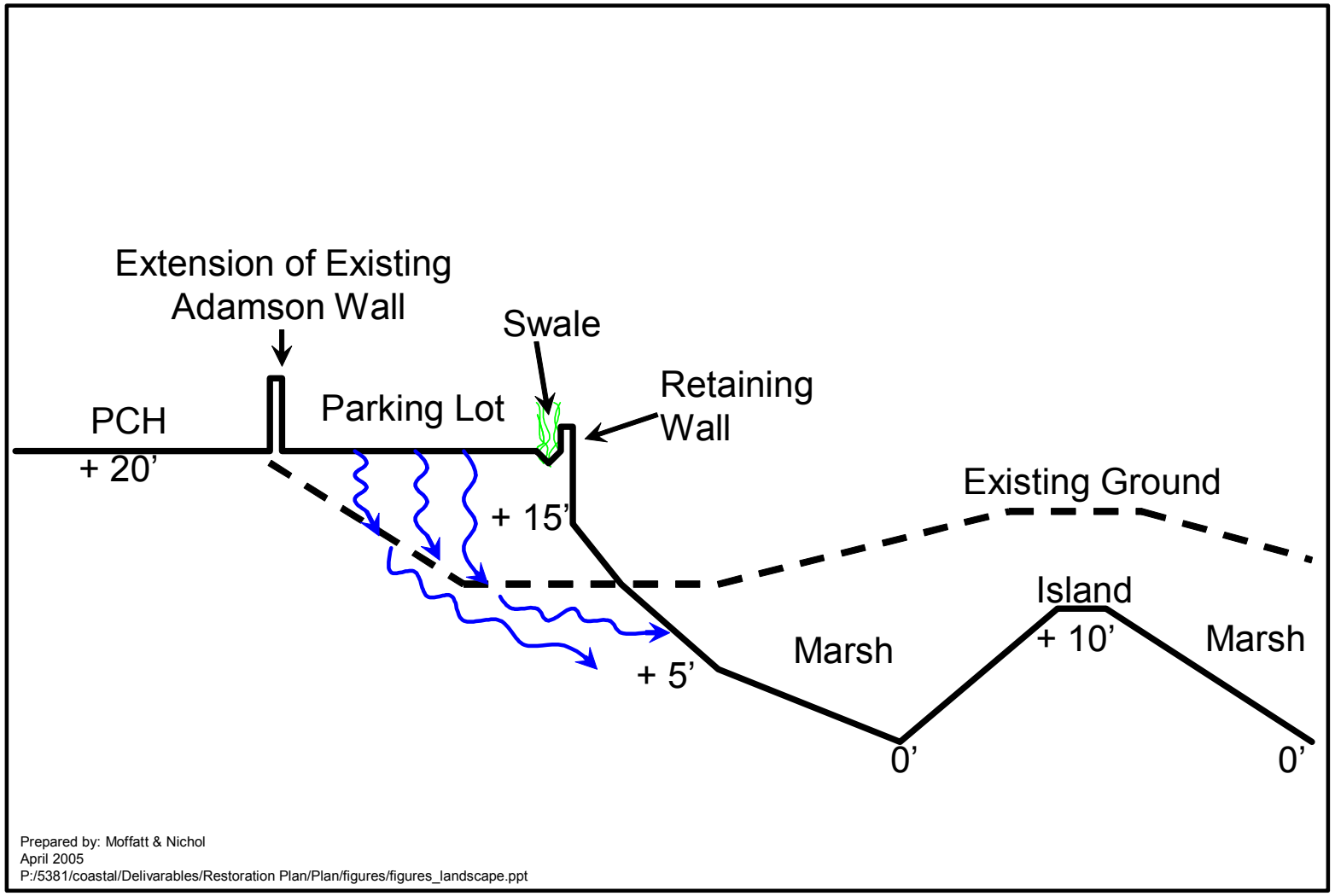
One type of stones are manufactured by a company named Uni Eco-Stone, and sold locally by Acker Stone in Ontario, California. Other types of stones were investigated but this particular



Final Malibu Lagoon Restoration and Enhancement Plan	Conceptual Area of Permeable Pavement	Figure 4



Final Malibu Lagoon Restoration and Enhancement Plan	Concept Cross-Section of Permeable Pavement	**Figure 5**



Final Malibu Lagoon Restoration and Enhancement Plan	Proposed Parking Lot Cross-Section Looking East	**Figure 6**

brand was most suitable for parking areas and is able to support the weight of buses and large vehicles. Guidelines for use of this material are provided in Appendix A.

The performance of the permeable pavement also depends on the quality of construction, and the extent of maintenance. Maintenance is required to reduce clogging of the coarse rock bed between and below the pavers by regular street sweeping. Sweeping at a frequency of every six months will prolong the life of the pavement.

The permeable pavement can percolate significant storms, depending on storm intensity. The manufacturer indicates that severe storms of up to the 50-year storm can be captured. Assuming that storm intensities will likely exceed the infiltration capacity of the permeable surface, additional measures to capture storm water are addressed below. The life of the permeable pavement is estimated to be approximately 15 years, based on construction, maintenance, and environmental conditions. When they no longer become effective, they should be entirely replaced rather than repaired.

Permeable pavements cost approximately double the cost of standard asphalt concrete parking lot surfaces. Standard parking cost $5 per square foot to construct, and permeable pavement areas cost $10 per square foot maximum to construct. The new parking lot at Malibu Lagoon as shown in Alternative 1.5 may be approximately 1 acre in area, or 45,000 square feet. Thus the cost to construct a standard new parking lot is approximately $225,000 while the cost to construct a permeable pavement parking lot is approximately $450,000 as shown in Table 1.

Table 1 - Malibu Parking Lot Construction Material Options

Construction Material Options	Unit Cost Per Square Foot	Area in Square Feet	Total Construction Cost in 2005 Dollars
Standard Asphalt/Concrete	$5.00	45,000	$250,000
Permeable Pavers	$10.00	45,000	$450,000

Drainage Swales

Another method of controlling and filtering drainage is use of drainage swales to promote infiltration and provide for additional habitat at the site. Drainage swales can be installed along the perimeter of hardscape areas such as the parking lot to intercept surface runoff that is not infiltrated into the parking lot.

A concept layout for swales is shown in Figures 7 and 8. The conceptual cross-section of the swale is shown in Figure 9, and is 3 feet deep and 9 feet wide with in a V-shaped cross-section. The side slopes are at 33 degrees, with changes of 1 foot vertically to 1.5 feet horizontally. These dimensions are applicable to future bioswales at the site for scenarios of the parking with and without permeable pavement. The bioswales are beneficial in either case and do not occupy a significant amount of surface area so they do not preclude other hard- or softscape from being

installed at the parking lot area. The two layouts for bioswales depend on the slope of the parking lot surface. Swale scenario 1 is a relatively flat parking lot or one sloping slightly downward toward the south (lagoon-side) outfitted with swales running along the south and west perimeters of the site and within the turnabout. Swale scenario 2 is a parking lot sloping downward to the north away from the lagoon. The swales would be located along the north lot edge and within the turnabout.

The drainage swales are intended to be large enough to hold runoff from the 100-year storm before it begins to overflow. Water retained within the swales would gradually percolate. Habitat formed within the swales would be designed to be complementary to the wetland. Specific vegetation types will be determined upon final swale design.

Both swales and permeable pavement would be used in compliment with permeable surfaces around the parking area consisting of decomposed granite and native California bunchgrasses, rather than hardscape access areas such as sidewalks and turf as exists today. Figure 10 shows possible locations of these softscape features.

The costs of swales are less expensive than parking lot hardscape, as the cost is mainly attributed to earthwork and landscaping. Maintenance is required for weeding, removal of exotic specifies, and replanting of dead natives. Overall the costs of swales should be less than parking area hardscape (on the order of $10,000 or less to install) and the benefits may be greater as both infiltration and habitat are enhanced.

2.1.2 Redirection of Storm Water Away From the Lagoon

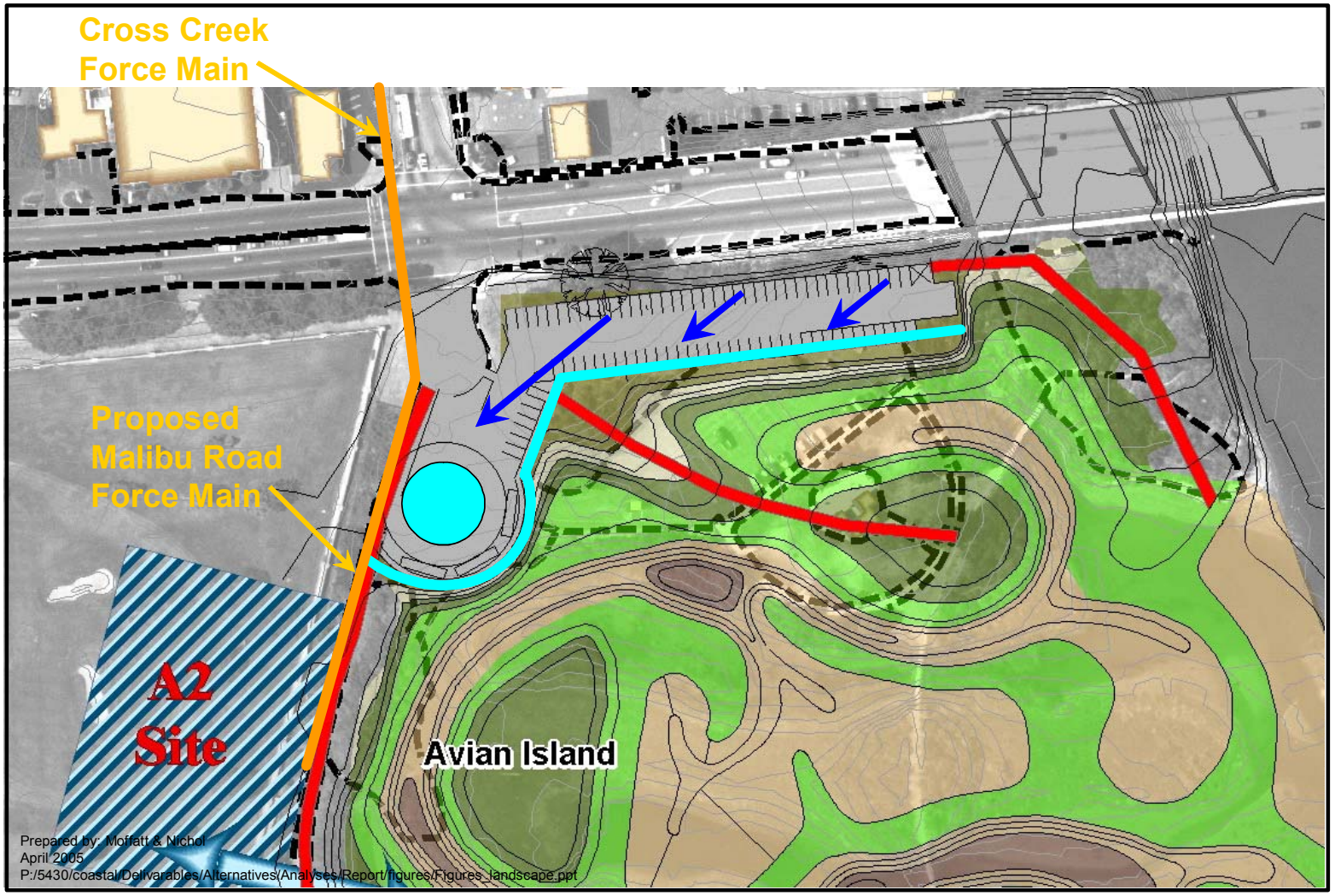
In addition to creating greater impervious surfaces for storm water management, redirecting storm water away from the lagoon and toward other appropriate drainage facilities is an option to supplement the installation of permeable surfaces. Two options are described below and many more could be conceived.

Slope the Parking Lot Toward PCH

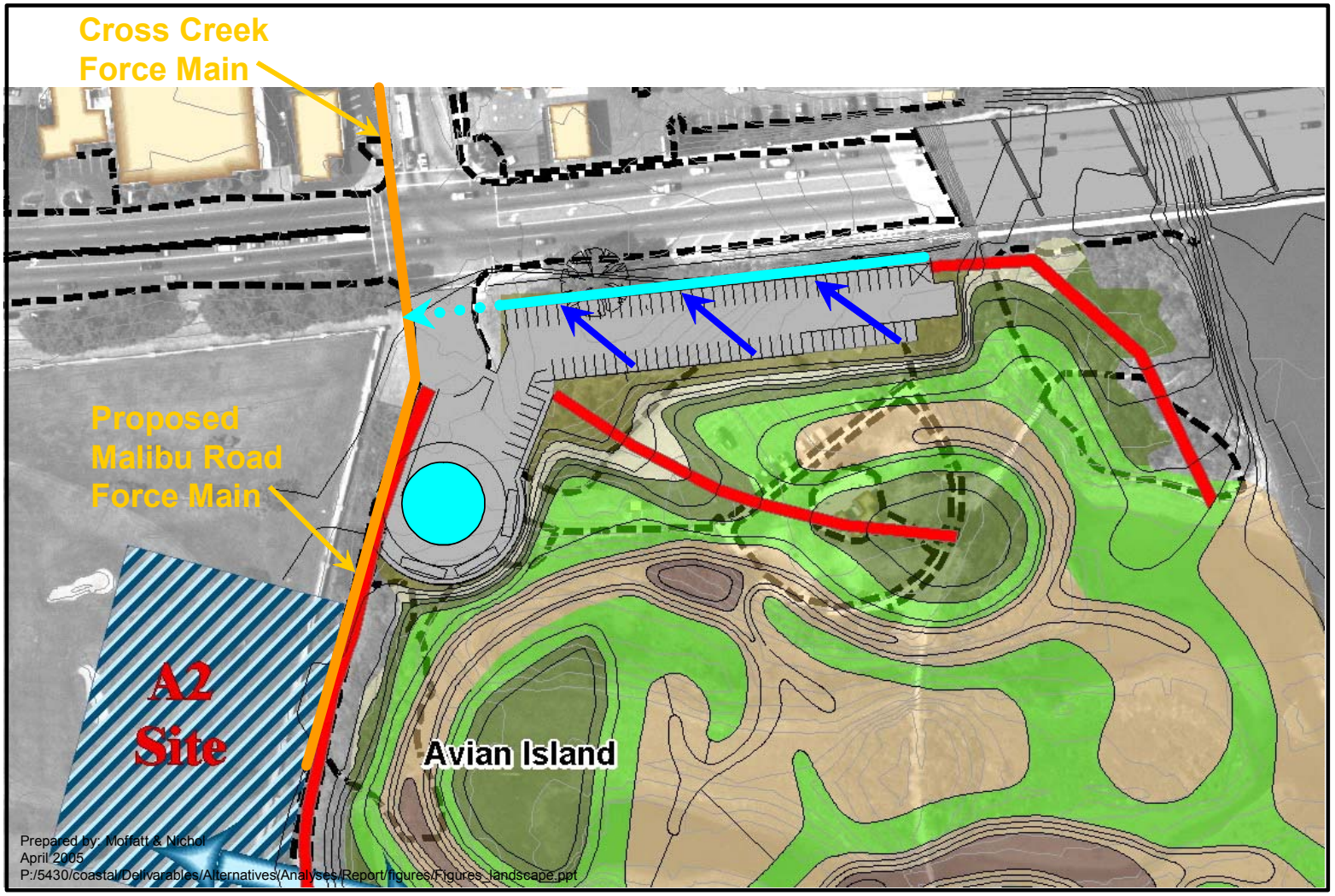
The lagoon State Park parking lot could be sloped downward toward the north to promote drainage away from the lagoon rather than toward the lagoon as presently occurs. As shown in Figure 8, such drainage could be conveyed to a swale or other conveyance feature (trench or pipe) and conveyed farther away from the lagoon.

Route Parking Lot Drainage to the Future City Drainage System

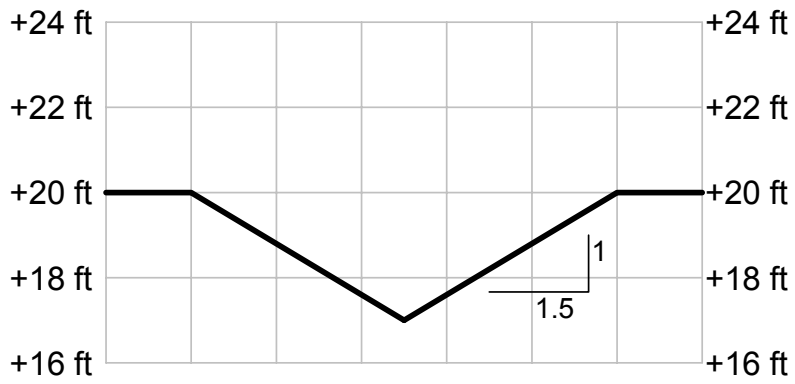
Another option for managing storm water at the State Park is to route drainage westward toward the collection sump for the City's future force main line along Malibu Road. The City intends to install a treatment plant for storm water and dry weather flow near Cross Creek Road and Civic Center Way, with a force main line pumping water from near the Malibu Colony north to the plant, bypassing the State Park parking lot. Drainage off the future parking lot could be routed to the sump near Malibu Colony at the south end of the future force main line, and then be included in water pumped upstream toward the future treatment plant. The City indicated sufficient capacity exists to accommodate the parking lot drainage (Yugall Lall, Personal Communication, May 13, 2005)



Final Malibu Lagoon Restoration and Enhancement Plan	Concept Drainage Bioswales at South Parking Lot Perimeter	**Figure 7**



Final Malibu Lagoon Restoration and Enhancement Plan	Concept Drainage Bioswale at North Parking Lot Perimeter	**Figure 8**



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Final Malibu Lagoon Restoration and Enhancement Plan	Cross-Section of Concept Bioswale	**Figure 9**

Final Malibu Lagoon Restoration and Enhancement Plan	Softscape Areas of Decomposed Granite and Native Growth	Figure 10

2.2 IRRIGATION

Nuisance water can also be inadvertently contributed to the lagoon by temporary and permanent irrigation of plantings at landscaped areas. As a natural habitat area, permanent irrigation should not be installed or used ever. In some instances supplemental irrigation is warranted to assist in the establishment of plants. The form of supplemental irrigation may be passive or active depending upon the final restoration design, seasonality of restoration work, and extent of habitat and anticipated duration of required irrigation. Active irrigation would include the implementation of a temporary irrigation system (overhead spray, drip, tended hand watering, or a combination of these methods) to assist in establishment of plant materials. For a passive system, a hydrophilic amendment would be used in the planting soils or as a binding agent for seed. Given the coastal location of the project site, coastal fog and high humidity provides adequate atmospheric moisture to support seed germination and surface soil moisture levels necessary for plant establishment during most portions of the year. This may be a viable alternative to installation of an irrigation system at the site. Use of turf at the site is also not recommended.

1. All temporary irrigation must be installed in shallow buried areas along the ground surface to avoid disturbance to wetland habitat yet still remain hidden.
2. Temporary irrigation should be automated, utilizing control clocks of current technology with multiple program and cycle features with battery backups.
3. No manual unattended irrigation should occur either with portable irrigation heads or manual control valves, except where a manual control valve also includes an automatic shut off timing device. Watering by hand-held hose should be permitted in all areas.
4. Temporary irrigation should include the following equipment:
    a. High flow shut off valve or breakaway shut off valves;
    b. Automatic Irrigation system;
    c. Rain shut-off device;
    d. Anti-drain valves to eliminate low head drainage; and
    e. Master control valve located at the point of connection.
5. Approved backflow prevention devices should be required for all new temporary irrigation systems.
6. Minimize or eliminate the use of herbicides and pesticides to protect habitat. An integrated pest management (IPM) program should be developed and implemented to wholistically address the problems of pests and weeds.
7. Only apply pesticides/herbicides, if needed, consistent with State-wide policy regarding pest control in all State parks. This may be found on the State intranet website http://search.parks.ca.gov/ and following on to “Department Policies” and then on to DOM (Department Operations Manual), and then to section 0700 “Pest Control.”

8. All temporary irrigation must be inspected regularly to ensure appropriate function.
9. No reclaimed water may be used for temporary irrigation within the wetland.
10. Consider applying salt water irrigation to salt-tolerant habitat areas susceptible to weed infestation by non salt-tolerant weed species.
11. A contingency irrigation plan should be prepared prior to revegetation activities to facilitate rapid installation if the need arises.

2.3 CIRCULATION

Water within the lagoon needs to circulate to remain of suitable quality for use as habitat. Improvements to circulation from existing conditions are an important project objective and this plan sets forth steps to verify that circulation has improved and signals to indicate the need for system modifications to maintain improved conditions. Target circulation improvements are detailed for winter, summer open and closed lagoon conditions. Verification of circulation improvements requires monitoring that is addressed in this section, and in more detail in Section 5.0 of this document. The monitoring parameters specifically address the spatial and temporal variability of circulation within the lagoon and provide performance targets to facilitate future adaptive management modifications.

2.3.1 Open Conditions

Circulation improvement under open lagoon conditions will require comparison of existing conditions with expected restored conditions. There are two main approaches to this that can be implemented separately or together, depending on the desires of the landowner. One approach is to quantify tidal flushing and resulting water quality conditions. Another approach is to directly measure flow velocity continuously. Both approaches are described below.

Quantify Tidal Flushing and Resulting Water Quality

The effort to quantify tidal flushing and resulting water quality will directly relate circulation with water quality, and require more intensive analyses. This method consists of the following steps outlined below.

1. Create a rating curve that provides an estimate of the water depth to lagoon volume. This can be done using depth data from a stationary data logger (suggested to be the YSI 600XL or equivalent) at the western arms and the main lagoon, and using topography/bathymetry data recorded as periodic surveys of the lagoon. Both the use of the data loggers and surveys are addressed in more detail in Section 5.0, Monitoring Plan, of this document.
2. Create a simple water budget from the rating curve and other data (described below) that yields the volume of daily tidal exchange and the flow velocity. Daily tidal volume exchange indicates the rate of tidal flushing and water residence time in the lagoon. This volume of tidal turnover can be estimated for existing conditions and then compared to restored conditions to quantify the change in water turnover and relative age. Tidal flow velocity is a direct indicator of the scour of the tidal channels and resulting grain size. One project objective is to increase bed scour and grain size to reduce the sequestering of

nutrients and therefore improve water quality. The water budget and pertinent parameters can be estimated using the approach below.

- Track water volume changes over time (using depth and topography/bathymetry data) and plot relative to the tidal cycle at the mouth (using a tidal time series program such as WXTides or an equivalent).
- Estimate flow velocities at certain locations using bathymetric channel cross-section data and volume changes over time from the real time water depth data. Alternatively, tidal flow velocities can be measured continuously using a meter located within the western arm. The meter could be one of several available from Sontec (see Appendix B for more information) or an equivalent supplier and described in more detail in Section 5.0. The advantage to their use is that flow velocities would be provided continuously and not have to be calculated by staff but would be directly provided by the gage, and that data are improved in quality compared to what can be estimated indirectly from other data. The drawback to their use is their relatively high cost, and the problem of securing the gage from theft, damage, and vandalism in this exposed public location. The gage can be insured against damage and theft, and could likely be secured and camouflaged to a certain extent to reduce public interest. The gage would also require regular monthly maintenance and data management. Other gages were investigated such as those by Marsh-McBirney but that supplier indicated they are not continuously recording gages and may not meet the measurement objectives, but could be used for periodic spot checks of velocity to supplement any calculations made by staff. Their gage information is in Appendix C.

3. Identify the extent of penetration of saline, oxygenated, and cooler (oceanic) water exchange in the western arm sites at various tide levels using water quality data loggers such as the YSI 600XL or equivalent described in Section 5.0.
4. Quantify the critical tidal elevation that induces flushing of the western restored areas and the frequency of that tidal elevation.
5. Determine the acceptability of the flushing condition based on water quality data collected as part of the monitoring program specified in Section 5.0.
6. Install the monitoring system at least 1 year prior to restoration activities for data to compare to post-restoration conditions. Alternatively, the system could be installed after restoration, and conditions in restored areas compared to those in the main channel for the same time periods to enable inferences of acceptable differences between the two locations. This second option is less desirable than the option of installing a system prior to restoration.

2.3.2 Closed Conditions

Circulation under closed lagoon conditions will be more difficult to estimate due to the relatively low magnitude velocity of water motion. Circulation can be measured directly by various methods, or ascertained indirectly by measuring water quality parameters that are a function of circulation and other variables.

Direct measurement of water movement can be measured using either a stationary continuously-reading velocity gage or hand-held instruments or both, or visually estimated using floats (such as fruit drops done for the Malibu Lagoon Feasibility Study). Circulation will be very slow and thus any sensor used will have to be very sensitive to make accurate measurements.

A suitable stationary sensor would be one of those offered by Sontec and described in Section 5.0 and Appendix B. It should be mounted within a suitable location within the western arms, such as the location used to estimate tidal flow velocities under open conditions. The initial location considered suitable is near the downstream end of existing C Channel. This location will also be the similar downstream end of the future channel.

Hand-held instruments can be obtained from similar suppliers (such as Marsh-McBirney) and even forestry supply stores. They are small meters suspended into the water by a line held by the user. These gages are fairly reliable and can be used to supplement data collected by a stationary continuous data logger.

Float-tracking studies can be used to estimate circulation in a rough fashion during certain events. They can supplement stationary measurements and even hand-held instruments by providing a synoptic view of lagoon water movement (simultaneously over the entire lagoon) over a relatively short time-frame such a one day. Float tracking is not as accurate as direct metered measurements, but can give a "big picture" view of the system and is therefore useful.

Indirect estimates of circulation can be obtained by measuring water quality parameters influenced by circulation such as dissolved oxygen (DO), water temperature, oxygen-reduction potential (ORP), and salinity throughout the water column and particularly within the bottom of the water column. These data will not provide direct indication of circulation, but their indicator status of the process of water exchange will confirm conclusions generated from measured data.

Improved circulation over time at the western arms compared to existing conditions can be inferred based on criteria such as the number of days at a given sample location and depth where:

- Dissolved oxygen is less than 3 milligrams per liter (mg/l);
- Water temp > 25°C; and
- ORP is < -100.

Alternatively, a relative comparison of the same parameters of water quality conditions in the western arms and in the main channel may be a better comparison as it will account for seasonal differences. This comparison also places the restored western arms area into context with the main channel.

It is important to note that until source reduction efforts are implemented, reductions of the magnitude and duration of eutrophic conditions within the closed Malibu Lagoon will be limited.

3.0 HABITAT PLAN

The Habitat Plan addresses the initial enhancement and establishment of habitats within the restored lagoon system as well as the on-going maintenance and management activities required to ensure that restoration habitat objectives are achieved. Adaptive management is an anticipated element of the Habitat Plan. Adaptive management will be required to respond to variability in the physical and chemical conditions manifested under the lagoon restoration plan.

3.1 HABITAT DESIGN

3.1.1 Slopes and Sediment Types

Habitat restoration within the restored lagoon is highly dependent upon development of suitable hydrologic and soil conditions and the availability of desirable reproductive plant materials to colonize the restoration areas. To accomplish the desired restoration, it will be necessary to design the site with appropriate consideration of elevations, slopes, and sediment characteristics. Table 2 outlines the general design slope, elevation, and sediment criteria of the habitats to be targeted in the project development. These criteria are provided at this stage to provide a design context, however further refinement will be required in project design and engineering in order to achieve habitat objectives.

Table 2 – Habitat Colonization Criteria

HABITAT TYPE	ELEVATION (FT. MSL)	SLOPE GUIDELINES	SEDIMENT CONDITIONS
Subtidal Gravel/Sand Bar	-2 to -1	Any slope, slopes will be dictated by the natural angle of repose following storm events and tidal action	Coarse sand and gravel typically greater than 2 mm grain size.
Intertidal Gravel/ Sand Bar	-1 to +4	Any slope, slopes will be dictated by the natural angle of repose following storm events and tidal action	Coarse sand and gravel typically greater than 2 mm grain size.
Sand Beach	+4 to +6	Any slope, slopes will be dictated by the natural angle of repose following storm events and tidal action	Sand typically between 0.1 mm and 2.0 mm grain size. Sands may be substantially derived from coastal beach sources
Subtidal Softbottom	-2 to 0	Any slope, slopes will be dictated by the natural angle of repose following storm events and tidal action	Muds to sands typically ranging from 0.001 to 2.0 mm. Coarser materials will be present in higher energy environments along the main channel through the lagoon

HABITAT TYPE	ELEVATION (FT. MSL)	SLOPE GUIDELINES	SEDIMENT CONDITIONS
Mudflat	0 to +3	Shallow slopes typically less than 25:1. Within the western lagoon slopes may be steeper along channel fringes.	Sediments are anticipated to be very fine sands to muds (0.001 to 0.08mm). Areas are typically depositional with sediment of both organic and mineral origin being represented.
Marsh	+3 to +5	Shallow to moderate slopes typically less than 5:1. Where slopes are shallower than approximately 50:1, increased tidal channels may be required to reduce sediment saturation. All marsh areas must have positive drainage such that water does not pond at low tides to cause absence of vegetation (mudflat).	Sediments are muds to fine sands with moderate to moderately poor drainage. Grain size should average between approximately 0.01 mm and 0.08 mm.
Nontidal Southern Coastal Salt Marsh (Alkali Meadow)	+5 to +7	Shallow slopes typically less than 10:1. All areas must have positive drainage.	Sediments are muds to fine sands with moderate to moderately poor drainage. Grain size should average between approximately 0.01 mm and 0.08 mm.
Riparian	varies	Shallow to steep slopes typically between 2:1 and 10:1 located where consistent freshwater groundwater influence is found.	Sediments are well drained fine to coarse sands at freshwater inputs, including seeps.
Coastal Dune/Bluff Scrub	+7 to +9	Slopes vary considerably however for design, slopes should be designed between 4:1 and 10:1 for establishment, lower erosion, and maintenance.	Non-saline sands and low silt content sandy loam soils.

Design conditions are to be developed during final design using the general elevation, slope, and sediment criteria outlined above, along with a verification of the typical hydroperiod for the lagoon under the restored conditions and consideration of habitat transition and slope transition characteristics at a suitable design scale.

3.1.2 Topsoil and Sediment Salvage and Management

In developing habitat designs, it is anticipated that stockpiling and reusing suitable sediments will be necessary to obtain the physical and chemical conditions necessary to support desired biological communities. These aspects of the design must be integrated into the project engineering construction documents, and grading activities.

Because of the highly variable sediment conditions within Malibu Lagoon, it would be very easy to restore the desirable lagoon contours and fail to establish suitable conditions within surface sediments that are necessary to support desired habitats. For this reason, it will be necessary to closely monitor sediment conditions, stockpile desirable surface sediments, and place surface materials within appropriate habitat types as the site grading is finalized. To aid in the salvage and replacement of sediments for surface caps within the various habitat types, the total volume of sediment necessary to create a 1-foot thick cap of each type of sediment required to achieve the desired habitat conditions has been determined based on preliminary site designs as shown in Table 3.

Table 3 – Volume of Earth Material Needed for Planting

HABITAT TYPE	ACRES	SEDIMENT TYPE	CU. YDS.
Sand Beach	4.45	D_{50} between 0.1 mm and 2.0 mm. Sands may be substantially derived from coastal beach sources	7,200
Mudflat	5.59	D_{50} between 0.001 to 0.08mm. High organics are okay.	9,000
Marsh	5.08	D_{50} between 0.01 mm and 0.08 mm.	8,200
Alkali Meadow	3.28	D_{50} between 0.01 mm and 0.08 mm.	5,300
Coastal Dune/Bluff Scrub	1.22	Non-saline sands and low silt content sandy loam soils.	2,000
TOTAL			31,700

While it is not necessary that all surface sediments be removed and replaced to construct suitable habitat areas, the volume of material required to achieve the desired surface sediment conditions should be tracked through construction to ensure that valuable and necessary sediments are not exported inadvertently.

Following final grading, it is likely that it will be necessary to adjust the drainage conditions of vegetated habitats to ensure positive drainage. It is likely that some delay will be required between grading and planting. Depending upon soil salinities, it may be necessary to leach soils prior to planting. This may be accomplished either by delaying planting through the rainy season or using irrigation.

Similarly, for habitats that are to be maintained as alkaline environments, it may be necessary to raise soil salinities to minimize invasion by undesirable weedy species. This may be accomplished through application of saltwater irrigation or retarding surface drainage and irrigating with brackish or freshwater at a rate that allows for high evaporative water loss.

3.1.3 Restoration Planting and Natural Establishment

The restoration of Malibu Lagoon is anticipated to rely heavily on natural recruitment into the desired habitat zones combined with directed revegetation. This has become a standard approach to large-scale coastal habitat restoration in Southern California. The effectiveness of restoration using natural recruitment is dependent upon a number of factors. These include the availability of desirable reproductive plant materials within the system, the extent of undesirable reproductive plant material that may recruit, the suitability of the site to support consistent recruitment, the anticipated rate of habitat colonization and the acceptability of anticipated species distribution and ratios if natural colonization occurs. Within Malibu Lagoon, the process, rate, and outcome of natural vegetation colonization will vary by elevation and habitat type. For this reason, directed restoration is anticipated to be required in a number of areas. Directed restoration will rely on container plantings, salvage and replacement of desirable plants presently found in the lagoon, and application of seed.

For plan development, the anticipated approaches to vegetated habitat restoration are outlined in Table 4, reflecting the most likely restoration approaches contemplated at this time. During final design and engineering, further consideration of approach will be undertaken and methods may change.

Table 4 – Approach To Vegetated Habitat Restoration

HABITAT TYPE	RESTORATION APPROACH	IRRIGATION METHODS	LEADING FACTORS IN APPROACH
Marsh	Natural recruitment and salvaged plant transplants (below +4) Salvage plant and container planting (+3 to +5)	Natural hydrology	Low elevations will receive high seasonal inputs of marine water and saline toxicity may be expected to control cattail spread and promote dominance by native halophytes. At higher elevations, freshwater discharge may be expected to dominate even during winter periods and cattail marsh may persist throughout the year. Increased effort to plant halophytes and brackish marsh emergent species will allow establishment adequate to preclude cattail monocultures. Under both open and closed conditions adequate soil moistures are anticipated to support both recruitment and establishment of target vegetation.

HABITAT TYPE	RESTORATION APPROACH	IRRIGATION METHODS	LEADING FACTORS IN APPROACH
Nontidal Southern Coastal Salt Marsh (Alkali Meadow)	Salvaged plant transplants Container plantings and seeding	Hydrophilic amendments Intermittent summer saltwater irrigation	Areas are subject to upland weed species invasion if salinities are low and primary space is available. Although positive drainage is required, relatively poor soil drainage caused by very flat slopes and fine-grained sediments will increase soil salinities to a point that will promote halophytes and kill weeds. Areas above regular inundation levels will receive poor recruitment by wetland plants predominantly dependent upon hydro-dispersal or wind dispersal to saturated soils. For this reason natural recruitment of target vegetation will be slow and weed recruitment will be high.
Riparian	Natural recruitment	Natural hydrology	Riparian vegetation is not specifically targeted in the restoration efforts but will be a resultant habitat where freshwater discharges occur along the wetland fringes above the higher tide lines. Natural recruitment of native willows and mulefat vegetation will occur where hydrology is acceptable. Promotion of hydrology will not foster long-term vegetation establishment since deeper rooting at the lagoon fringe will result in saline toxicity of plants once supplemental water is removed.
Coastal Dune/Bluff Scrub	Seeding and container planting	Hydrophilic amendments and potentially spray irrigation	Upland plant salvage and transplant is not typically efficient on a large restoration scale. Seeding of habitat is a proven technique for these habitat types, although container species often can be used to promote diversity through introduction of species that are poor recruiters from seed or which are typically out competed by dominant species of the habitat. Hydrophilic amendments may be adequate to establish upland habitats, however overhead irrigation may be required if sediments are saline.

Many of the desired species presently exist in the lagoon habitats that would be impacted by the proposed work and significant salvage and transplants may be undertaken to minimize the need for new plantings and to optimize the use of site native materials. A temporary on-site nursery area should be considered for the project. This would require the installation of a temporary overhead irrigation system using potable water. The system would be operated as needed to keep salvaged plants healthy until received sites are made available. Plant materials recommended to be used in the restoration of the lagoon are outlined in Table 5 below along

with the preferred application methods. Container size will vary depending on species, season of planting and location within the restored wetland.

Table 5 – Recommended Plant Pallete for Malibu Lagoon Restoration

PLANT NAME	HABITAT	PLANTING METHOD
Pickleweed (*Salicornia virginica*)	SCSM	seed & salvaged plant material
Parish's glasswort (*Salicornia subterminalis*)	SCSM	seed & salvaged plant material
Dwarf glasswort (*Salicornia bigelovii*)	SCSM	seed
Marsh jaumea (*Jaumea carnosa*)	SCSM	container
Saltwort (*Batis maritima*)	SCSM	container
Sea lavender (*Limonium californicum)*	SCSM	container
Alkali heath (*Frankenia salina)*	SCSM, AM	flat
Southwestern spiny rush (*Juncus acutus*)	SCSM, AM	container & seed
Salt-cedar (*Monanthoschloe littoralis*)	SCSM, AM	flat
Saltgrass (*Distichlis spicata*)	SCSM, AM	salvaged plant material
Salt marsh fleabane (*Pluchea odorata*)	AM	container
Purple sand verbena (*Abronia umbellata)*	CD/BS	seed
Silver beach bur (*Ambrosia chamiisonis)*	CD/BS	seed
Beach primrose (*Camissonia cheiranthifolia*)	CD/BS	seed
Beach morning glory (*Calystegia soldanella*)	CD/BS	seed
Extuary sea-blite (*Suaeda esteroa*)	CD/BS	container
California box-thorn (*Lycium californicum*)	CD/BS	container
Dune buckwheat (*Eriogonum parvifolium*)	CD/BS	seed
Coyote bush (*Baccharis pilularis*)	CD/BS	seed
Bladderpod (*Isomeris arborea*)	CD/BS	container
Lemonadeberry (*Rhus integrifolia*)	CD/BS	container

SCSM-Southern California Coastal Salt Marsh; AM-Alkali Meadow; CD/BS-Coastal Dune/Bluff Scrub

3.2 INITIAL HABITAT RESTORATION

3.2.1 Maintaining Unvegetated Habitat Areas

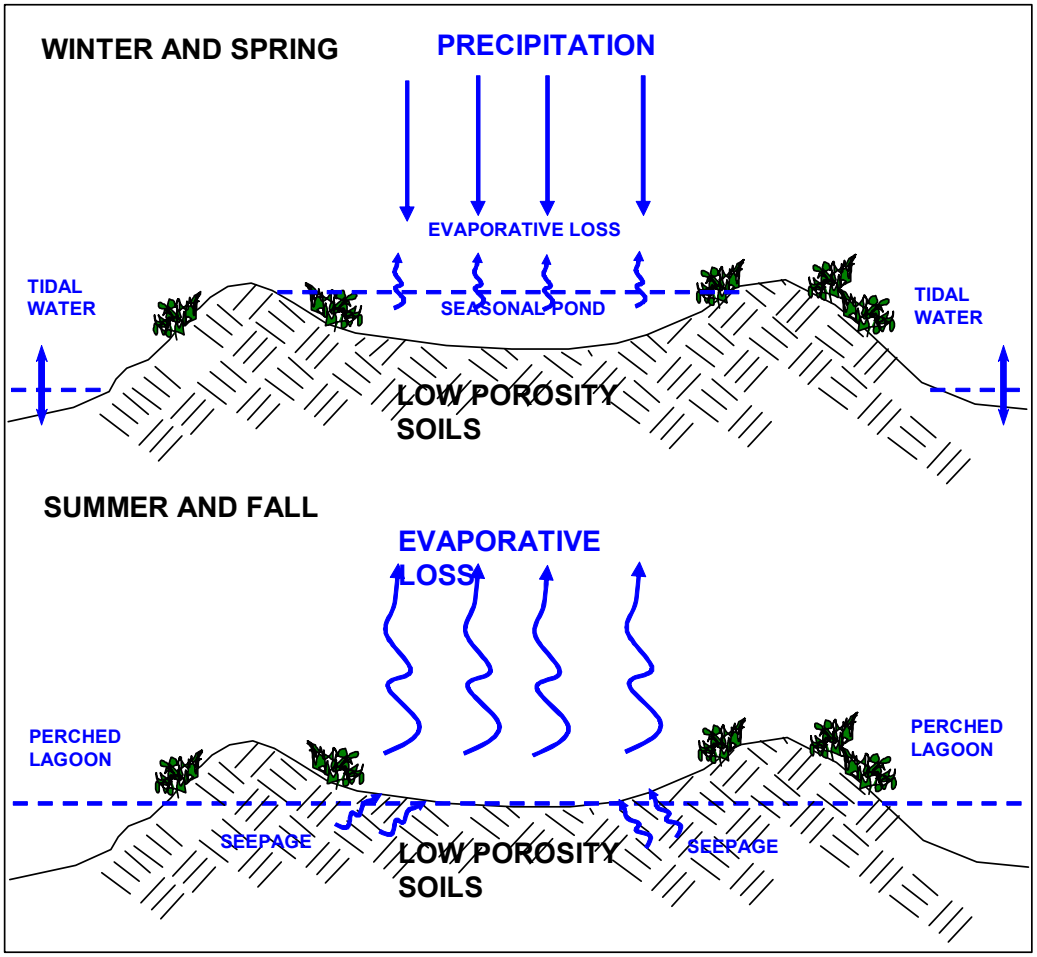
The Malibu Lagoon restoration program incorporates both vegetated and unvegetated habitat areas. Included among the unvegetated habitat areas are frequently submerged habitats such as mudflats and channels as well as exposed avian islands, beaches, and dunes. The highest functionality of these habitats depends on maintaining their open nature. For frequently submerged habitats, this is accomplished naturally by maintaining very low oxidation-reduction potential (ORP) or high scour. However, for habitats located in areas of lower inundation frequency, opportunistic vegetation often consumes open ground rapidly. To combat the expansion of undesirable vegetation into the naturally open habitat areas, there are several approaches that may be taken.

For beach and dune habitats it is important to minimize the accumulation of fine sediments that retard water and nutrient drainage and impart sediment stability. Desirable dune vegetation is tolerant of very low nutrient supplies and shifting sediment conditions. Where sediments are stabilized, opportunistic and often invasive annuals and herbaceous perennial plants often become established. For this reason, development of dunes will only be highly successful in areas where fine sediments are not accreted, nutrient supplies are kept low, and sediments are unstable. Regular seasonal lagoon breaches and natural closure frequencies are suitable to maintain unvegetated beaches along the coastal fringe. For dunes, the lagoon breaches are too frequent for regular dune development along the barrier beach. Adjacent to the Malibu Colony fence line, the stability of the beach is high and it may not be possible to maintain the open vegetation of a natural dune system. This site may be suitable for development of a transitional upland area. However, there may be greater opportunity to support desirable conditions at the eastern end of the beach where a degraded dune system presently exists.

For avian islands it is desirable to maintain sparsely vegetated or unvegetated areas. This can be accomplished through two recommended methods. The first is to develop a site that lacks soil by using well-drained cobble and gravels with no fine sediments. An example of such an island is the mid-lagoon shoal that often forms as a result of major storm events. Over time, these islands eventually trap finer sediments and debris as well as receiving considerable nutrient inputs from bird wastes. As fine sediments and nutrient levels rise, sparse opportunistic vegetation becomes established. Over time, the islands will eventually be consumed by vegetation unless they are flushed of fine sediments either by storm flows, high water volume rinses, or mechanical reworking of the cobble and gravels on an as-needed basis. Such island cleaning may be required on a 2 to 10 year maintenance frequency. The second recommended approach to maintaining unvegetated or sparsely vegetated areas for avian islands is to reduce soil and surface drainage thus reducing sediment ORP and increase soil salinity. Following this approach, poorly drained soils are used to create the island surface and the top of the island is made to be slightly concave so that it holds water when flooded either by natural rainfall, artificial pumping, or infrequent inundation, generally through a controlled structure. By creating an internal basin, water loss principally occurs through evaporation and thus salts are concentrated on the island surface. This creates a salt panne environment that is sparsely vegetated by halophytes that are generally concentrated along the ponding edges.

Operationally, the salt panne basins are seasonally flooded during the winter and spring periods and dry during the summer and fall periods. Such ponded areas are often used as foraging areas by small shorebirds because of the controlled shallow depths and the often high concentration of brine flies and other insect prey species. During the dry summer season these areas are often used as nesting sites by such species as avocets. Examples of these types of salt pannes often exist in areas of hydraulic fills around bays and estuaries of Southern California. They are also a common feature in natural flood deltas of estuaries where major storms have scoured out depressions in the high marsh plains (Tijuana River Estuary, Sweetwater River Marsh), however most of these historic deltas have been lost from the region and natural examples are limited today. Figure 11 below shows a conceptual salt panne.

To maintain low vegetation cover within the salt pannes, it may be necessary to seasonally pump salt water into the basins on an infrequent basis to increase salinity levels. This should not require annual actions and can be accomplished during periods of tidal opening with a small (1 or 2-inch) gas powered pump. An alternative approach would be to lower the basin floor to an elevation that exists at or below the normal high water level of the lagoon so that natural evaporation of seepage increases salinity levels in the basin. The schematic in Figure 11 below illustrates these concepts around the salt panne avian island configuration.



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Final Malibu Lagoon Restoration and Enhancement Plan	Concept Salt Panne	**Figure 11**

3.2.2 Minimizing Habitat Losses from Seasonal Inundation

The same low oxidation-reduction potential that can be used to limit vegetation growth where it is undesirable, will also be of concern in vegetated habitats. Because of the long-term seasonal inundation of much of the lagoon habitat during the summer months, vegetation dieback can be expected in these areas. While it is not fully possible to correct the problems associated with long-term inundation on vegetation communities, it is possible to reduce the effects by taking the following steps:

1) Develop an undulating topography within the seasonally inundated habitats in order to ensure that the extent of inundation is varied across the terrain. This will ensure that not all vegetation is subject to the same potential risk of loss;
2) Incorporate vegetation that tolerates prolonged exposure to anoxic soil conditions into restoration efforts. Such species include: *Jaumea carnosa, Batis maritima,* and *Spartina foliosa*
3) Incorporate vegetation into restoration efforts that rapidly expands into unvegetated areas by seedling recruitment. Such species include: *Salicornia virginica and Salicornia bigelovii.*
4) Promote increased oxygenation of waters during inundation periods.

Lagoon water levels typically rise to a maximum elevation at the very end of the closed lagoon period. Water level data from others (M&N, 2005) indicates water levels stabilize at approximately +5 feet above mean sea level (msl) for the summer, then rise another one to two feet for approximately the last two to four weeks of the closed period water levels. This last short term rise in water level is caused by releases from upstream water impoundments such as the Tapia Plant. The lagoon habitat vegetation mosaic is adapted to maximum water levels at +5 feet msl. The short-term period of super water level elevations is too short to affect the distribution of vegetation and should not cause significant or long-term variations of lagoon habitat. No planning or design features are needed to address this condition.

3.3 ESTABLISHMENT MAINTENANCE

During early establishment of the restoration, it will be necessary to conduct maintenance that promotes the effective development of target habitats while preventing the establishment of non-target vegetation. Specifically, it is anticipated that it will be necessary to conduct focused invasive species removal from restoration areas. It may also be necessary to augment plantings of desirable target vegetation or conduct increased levels of maintenance to promote plant establishment or address identified problems.

In addition to normal establishment maintenance, adaptive management may be required to foster effective habitat development. It may be necessary to alter site topography or drainage, modify plant palettes to fit specific site conditions, or direct habitat restoration of a differing habitat zone. Adaptive management actions will be based on results from habitat monitoring, described later in Section 6.0.

3.4 LONG-TERM HABITAT MAINTENANCE

Malibu Lagoon is a system naturally characterized by alternate states of open tidal influence and closed brackish/freshwater pond conditions. As a result of the highly variable environmental conditions occurring within the lagoon, the lagoon is at great risk of invasion by opportunistic exotic species and the degradation of fringing habitats absent vigilant maintenance. Maintenance within the lagoon will require on-going exotic plant control efforts. The extent of such maintenance in the lagoon may be reduced if highly invasive exotic plants are controlled effectively in the watershed.

In addition to exotic species invasions within the lagoon, it is anticipated that high nutrient loading within the lagoon will continue to promote growth and expansion of opportunistic algae and fast growing vascular vegetation such as cattails over other species. The proliferation of ephemeral macroalgae and microalgae will further adversely effect oxygen levels within the lagoon and adversely impact aquatic animal communities as well as less competitive plants. The effective development of target aquatic habitats and associated communities is dependent upon both the improvement of existing lagoon environments and curtailing degradation from external sources, particularly the inputs of nutrients and control of exotic species in the watershed. Improvements to these external factors should be made a priority in a parallel effort to the lagoon restoration.

4.0 ACCESS, EDUCATION, AND INTERPRETATION PLAN

The access, education, and interpretation plan is shown in Figure 12. This plan provides for access at grade along the perimeter of the western arms complex at the location of the existing vehicle access route. Multiple interpretive nodes and areas suitable for educational programs have been identified, and multiple length interpretive loops provided to allow for a variation of docent led activities with exposure to multiple habitat types.

The most important element of the plan is the relocated parking area, moved back and elevated to a position along PCH that will be acoustically and visually buffered by a proposed extension of the "Adamson wall." This move will:

- Expand the area available for habitat, and if stepped retaining walls at the south and east are provided along that edge, it will allow for an even greater area of shallow-slope wetland margins;
- Allow more ground surface area to be available for wetland habitat restoration, including installation of potential adaptive management options such as the North Channel, if needed in the future depending on the footprint of slopes shown in the plans;
- Make it possible to implement the best management practices in the construction of the new lot as discussed above;
- Create a new bus drop and parking zone in addition to providing car capacity equal to that of the existing lot;
- Provide an elevated platform for initial orientation (designed to be sufficiently sturdy to not shake under average wind conditions for stable bird viewing with telescopes);
- Make access to the PCH bridge easier and more clearly defined; and
- Make possible the installation of an ADA accessible viewing tower at an elevation above PCH bridge in order to experientially re-integrate the full tidal/lagoon system of Malibu Creek that is currently bisected and fragmented by the PCH bridge.

The access plan provides for different experiential, teaching and management opportunities, with a number of "add alternate" components.

4.1 PERIMETER ACCESS

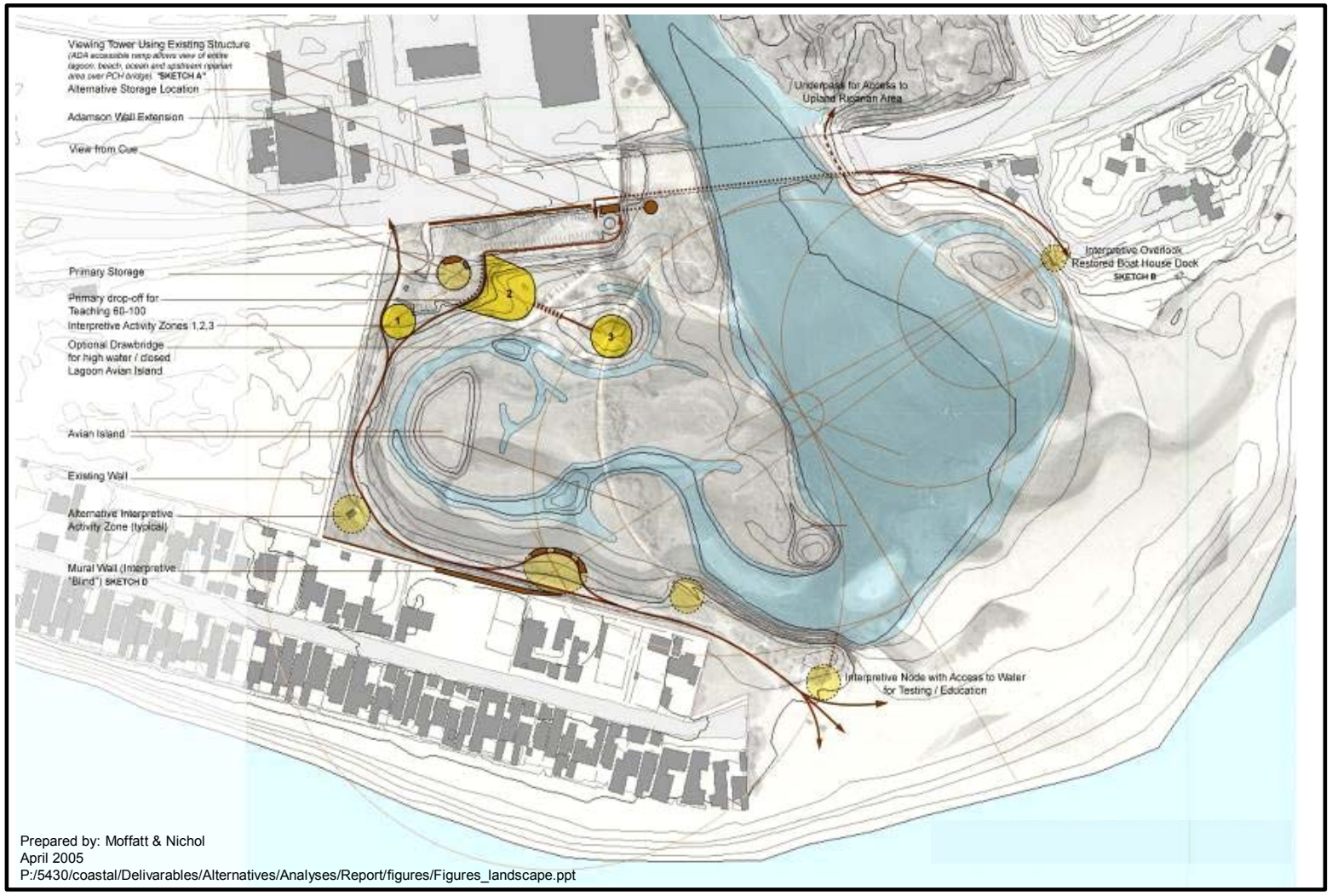
This plan, shown in Figure 12, will provide a primary beach access trail that is directly accessible from the Cross Creek Road intersection and bus drop-off zone. This approach provides for three primary interpretive nodes near the parking area, and optional locations for additional nodes for instructive features, benches for wildlife viewing, picnicking, painting, etc.

Access to the interior of the system in this alternative is limited to a single path along the axis of the entry/drop-off zone along a gently sloping peninsula (area "2") where the primary teaching can take place on picnic tables aligned along the trail, or in the optional amphitheater seating (north of trail axis at area "2"). The access continues across a short span, that could if designed

as a drawbridge to allow for a seasonal island in the approximate location of the existing turf/interpretive kiosk zone at closed lagoon conditions. While this interpretive node is envisioned as a cleared gathering area within a dominant restored wetland habitat, the grading of the island could allow for some of the existing sycamores to be retained for shade within a small upland component. Figure 13 shows the overlook that could be created for minimal intrusion.

Additional features of this plan include:

- Storage and restroom facilities near entry parking circle;
- Orientation and interpretive node at perimeter trailhead (area "1");
- Optional storage/restroom location built into "Adamson wall" at Lagoon Loop Trail gateway at east end of parking lot;
- Enhanced "Lagoon Loop Trail" access to the east lagoon over PCH bridge with interpretive signage and graphics;
- An underpass at the east abutment to provide improved access to the riparian habitat north of PCH and west of Serra Road;
- A loop trail extension arcing along the upland margin along the Adamson property (existing chain link is proposed for removal to allow for restoration and access);
- An interpretive overlook at a restored Adamson House dock shown in Figure 14 and boat house to introduce cultural tourists to the features of the nearby habitat island and lagoon system from the eastern vantage point;
- A continuation of the Lagoon Loop Trail to the beach below the Adamson House; and
- A possible mural wall separating the Colony properties from the perimeter trail as shown in Figure 15, including a "thick wall" element with integrated benches, interpretive displays including possible dioramas, and additional storage for teaching and testing equipment. The wall will arc toward the wetland margin to define a node within the access path defined on the opposite side by:
  - an "interpretive blind" concealing observers from the wetland complex and framing particular instructive views with integrated interpretive graphics (see sketches);
  - additional alternative Interpretive Activity Zone sites as appropriate to the docent led programs and to provide for expected user capacity for passive recreation (picnics, painting, study, etc); and
  - an improved self-contained restroom facility with vehicular access for servicing at the edge of the beach/upland area.



Final Malibu Lagoon Restoration and Enhancement Plan	Perimeter Access Plan	**Figure 12**

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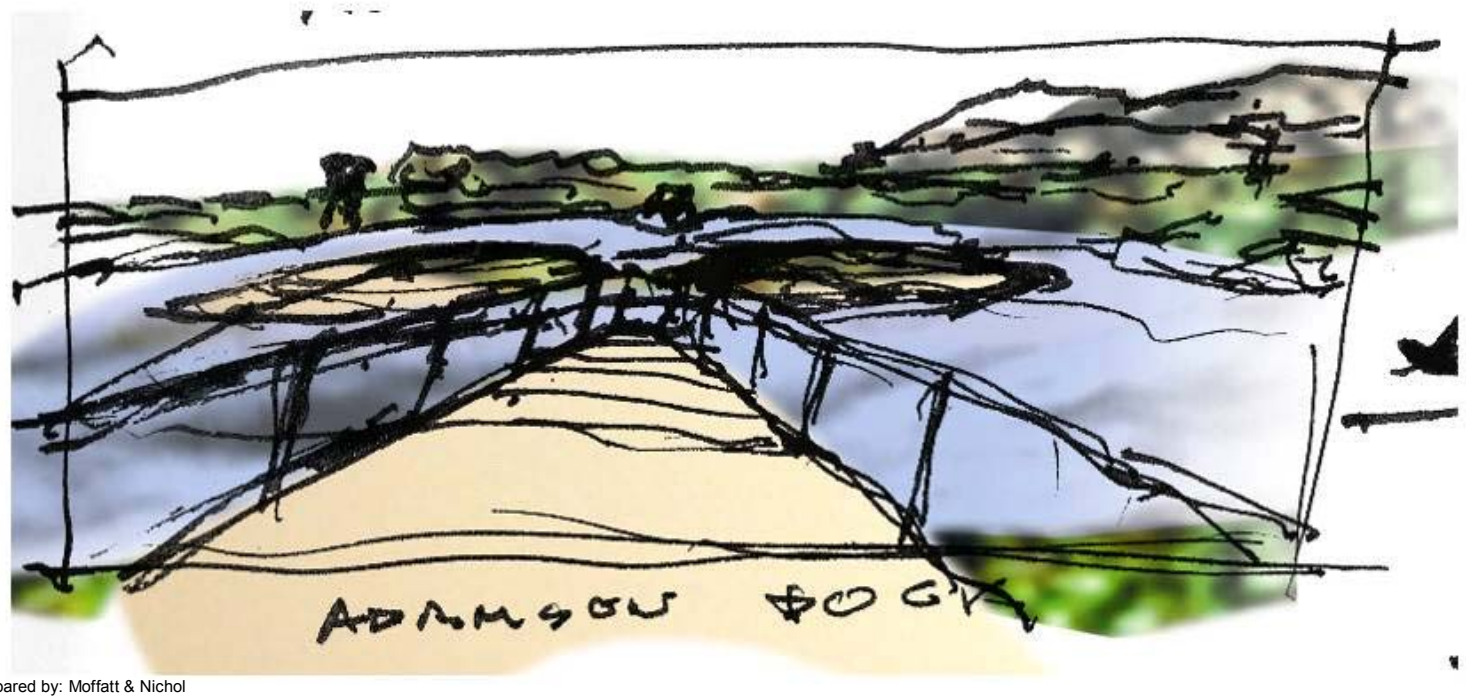
Final Malibu Lagoon Restoration and Enhancement Plan	Non-Intrusion Platform Option	**Figure 13**



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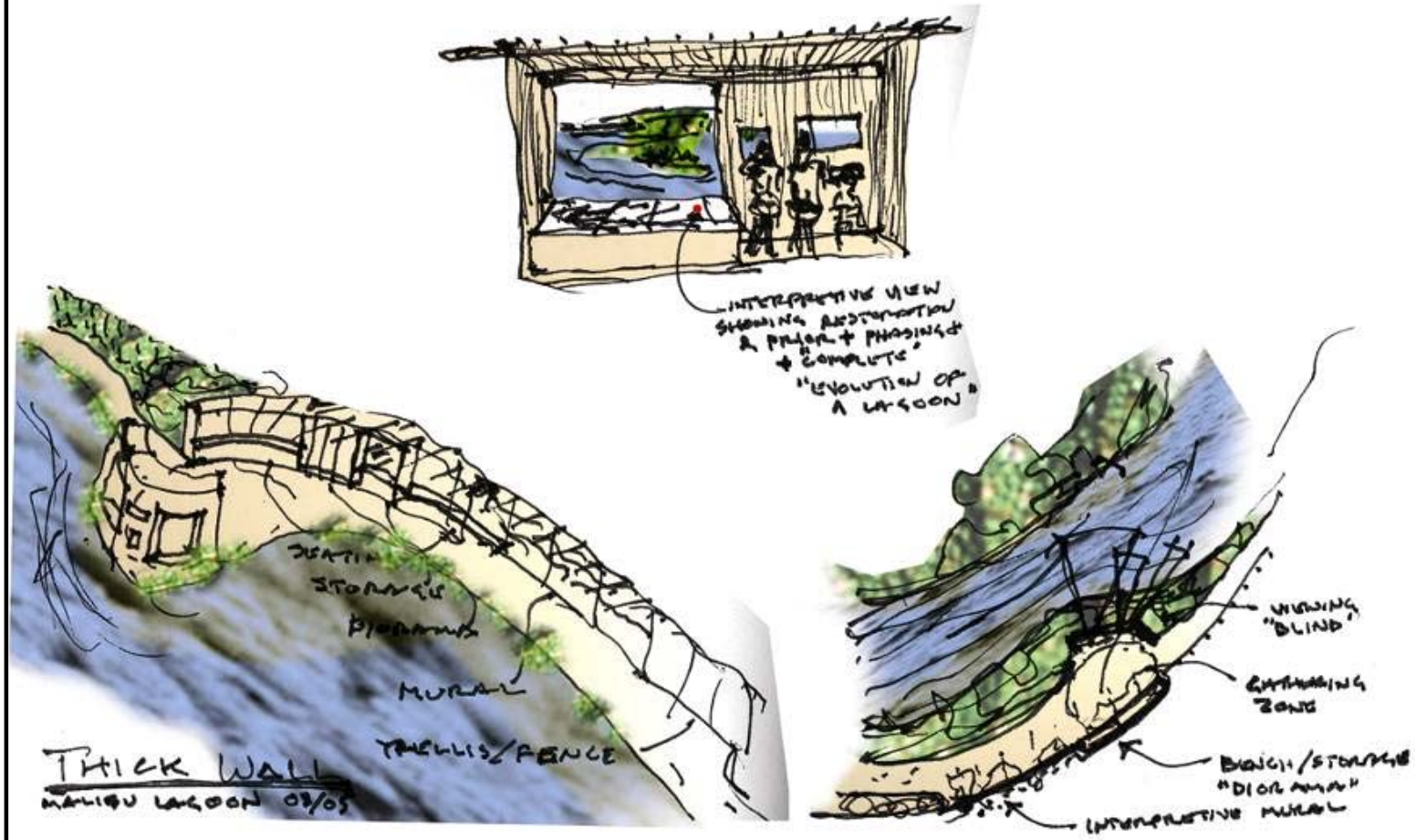
Final Malibu Lagoon Restoration and Enhancement Plan	Adamson Dock View	**Figure 14**



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Final Malibu Lagoon Restoration and Enhancement Plan	The Thick Wall and the Duck Blind	**Figure 15**

5.0 MONITORING PLAN

5.1 PURPOSE OF THE LAGOON MONITORING PROGRAM

The Malibu Lagoon monitoring program will be used to assess the existing floral and faunal assemblages at the lagoon, protect existing habitat, minimize impacts and document resource changes for application in future restoration programs. The primary monitoring program objectives are as follows:

- Set the baseline of biological, physical and chemical conditions for analysis of the project under the California Environmental Quality Act (CEQA) to minimize impacts to existing habitat and to evaluate future restoration success;
- Facilitate an evaluation of the effectiveness of the restoration to provide habitat for fish and wildlife;
- Assess progress towards restoration goals;
- Document changes in the ecology of the lagoon environment over time;
- Provide timely identification of any problems with the physical, chemical, or biological development of the lagoon, and;
- Assist in providing a technical basis for resource management of the lagoon system by documenting maintenance needs and enhancement opportunities.

5.2 ANNUAL REPORTING

The lagoon-monitoring program consists of annual sampling activities completed during each year prior to and following lagoon restoration activities. The monitoring program has been tailored to provide useful information to assess restoration and make sound management decisions. The annual report provides a data presentation and analysis format for assessing the status of the restoration project and evaluating changes in the site over the course of the program. Each annual report is to include a compilation of information collected for the specific year of sampling as well as a cumulative reporting for all prior monitoring years. The report shall further provide an analysis of data for the specific year and a cumulative analysis of change in the system, making use of information from preceding years. The annual reports are to accomplish the following:

- Identify the investigations or sampling completed for the specific report year;
- Document studies and surveys conducted and summarize sampling methods;
- Summarize information gathered during the year and provide aggregate information on sampling completed to date;
- Summarize restoration activities conducted during the prior year and provide an outline for future restoration work to be completed;
- Present an analysis of the data collected and provide an evaluation of the ecological development of the lagoon system;
- Document habitat values achieved through restoration efforts, and;

- Make recommendations regarding beneficial changes and/or additions to monitoring methodology and data collection and analyses.

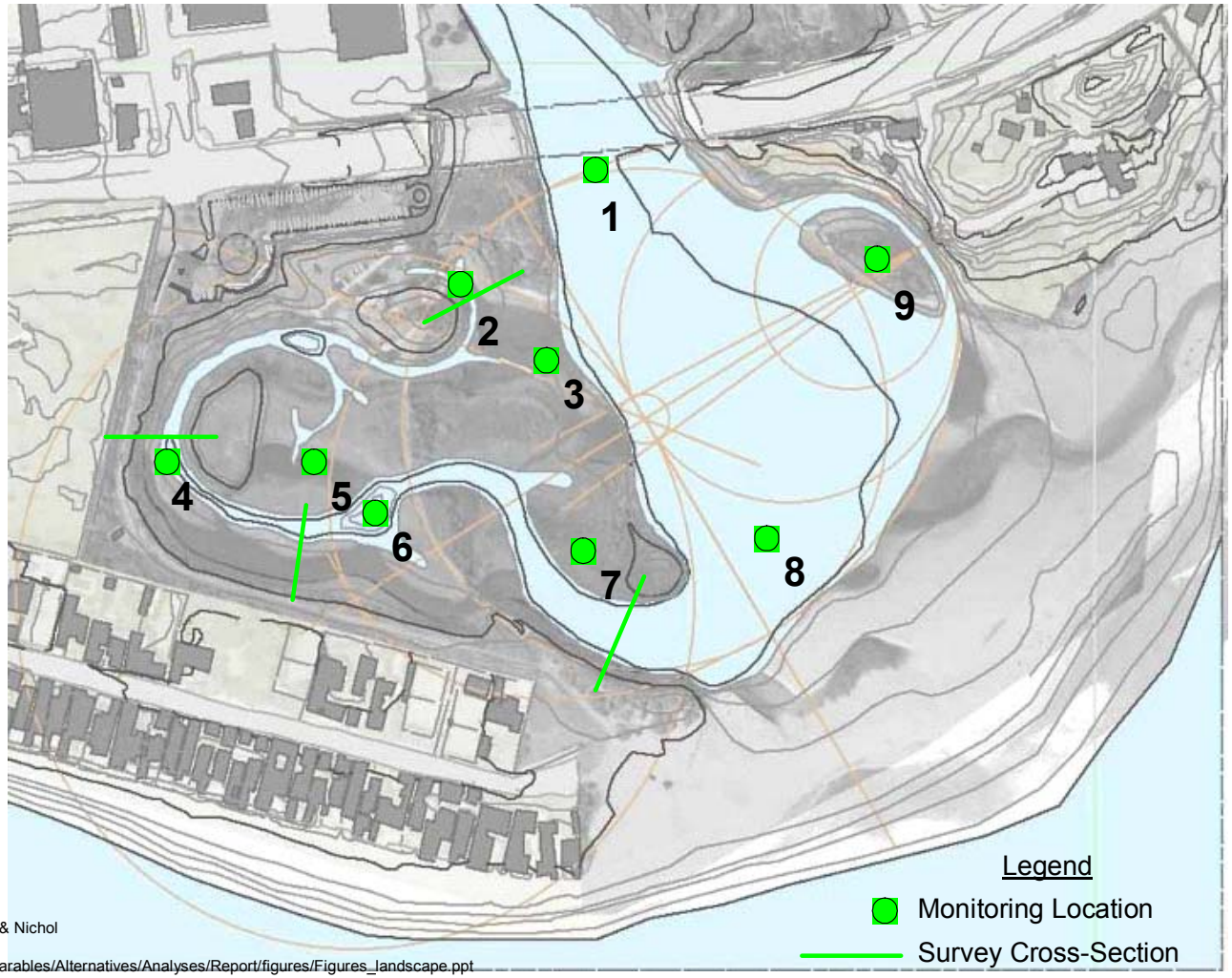
5.3 MONITORING PHILOSOPHY

The following monitoring plan includes an array of physical, chemical and biological parameters that all address different functional aspects of a healthy and sustainable lagoon system. The key to restoration of Malibu Lagoon will be observable improvements in the physical and chemical conditions that facilitate biological stability by the reestablishment and persistence of species diversity and native organisms well beyond the first 5 years following construction. In order to confidently measure improvements in the system, the monitoring program needs to:

1. Standardize sampling protocols to account for the inherent temporal and spatial variations as much as possible;
2. Select monitoring parameters that will directly address restoration goals and intended successes;
3. Acquire a reliable baseline dataset; and
4. Maintain parameter and technique continuity throughout the monitoring program.

Understanding baseline conditions prior to ecological restoration is imperative to accurately and quantitatively assess the physical, chemical and biological changes as a result of restoration efforts. While a gamut of previous monitoring information exists on Malibu Lagoon, the spatial and temporal variability of previous sampling, as well as variations in techniques, would make it difficult to apply the previous data sets as baseline conditions from which to evaluate future restored conditions. The most robust assessment of restoration performance will be provided by a standardized monitoring program that provides baseline and post-restoration data using the same parameters, the same techniques, functionally similar spatial sampling locations and constrains the temporal variability of sampling as much as possible. The monitoring sites are provided in Figure 16. Sampling consistency with continual consideration of the inherent dynamic nature of coastal lagoons is the most effective means to obtain reliable evaluation of restoration success.

The monitoring plan presented herein has been designed to be consistent the Comparative Lagoon Ecological Assessment Project (CLEAP) currently being conducted in Santa Cruz County (2ND NATURE, 2004). The monitoring plan may be slightly modified in the future to be consistent with forthcoming restoration monitoring guidelines prepared by the Southern California Wetlands Recovery Project (www.scwrp.org).



Final Malibu Lagoon Restoration and Enhancement Plan	Monitoring Locations	**Figure 16**

5.4 RESTORATION GOALS

Based on the initial goals prepared by the Malibu Lagoon Task Force, a series of detailed restoration goals have been developed to set measurable targets for the restoration program.

5.4.1 Physical

1. Improve water circulation during all hydrologic conditions (i.e., storm flows, tidally dominated open conditions, and closed conditions). Circulation directly relates to the stability of the restored lagoon bathymetry and morphology (quantity of sedimentation dynamics), grain size distribution (quality of sediments), and water quality (temperature, dissolved oxygen, salinity, and ORP.
2. Provide an optimum three-dimensional lagoon geometry to provide for maximum water circulation under all conditions, and a desirable and diverse habitat mix.
3. Improve storm flow and tidal sediment discharge characteristics to reduce the erosion and accretion of sediments within the lagoon and the maintenance requirements to sustain a functional lagoon system.

5.4.2 Chemical

1. Reduce sediment nutrient content. Previous research has identified that increased grain size of lagoon substrate will decrease available summer nutrient loads regenerating from the lagoon sediments, thus reducing the potential for eutrophication and low dissolved oxygen conditions during warm months of the year (Sutula *et al*. 2004).
2. Increased circulation and water exchange during tidally dominated and closed conditions. Increased circulation and water exchange will improve temporal and spatial frequency of oxygenated water contact with surface sediments, thus increasing organic matter decomposition and increasing the transformation of ammonia to nitrate. This, in turn, will facilitate the permanent loss of nitrogen, the limiting nutrient, from the lagoon through denitrification and reduce its supply to the primary producer communities.

5.4.3 Biological

1. Protect existing natural biological communities represented within Malibu Lagoon during and following restoration.
2. Reduce the incidents and geographic limits of depressed dissolved oxygen levels that adversely affect native lagoon communities.
3. Reduce predator encroachment in the lagoon habitats by improving habitat isolation during open and closed lagoon conditions.
4. Expand desirable native habitats and reduce habitat dominance by exotic species.
5. Promote habitat suitability for threatened and endangered species by increasing the available slough channel refugia habitat with sandy bottom for tidewater gobies and providing increased isolation of island habitats for seasonal snowy plovers and least tern use.

The ability of the restoration efforts to attain improvements in lagoon water quality may be significantly limited by the extreme watershed loading of annual nutrients to Malibu Lagoon. As management efforts continue to focus on reducing nutrient loading, the water quality benefits of restoration efforts maybe more likely.

5.5 PARAMETER SELECTION

Monitoring parameters have been selected specifically to support the restoration needs for the lagoon and to evaluate the progress towards restoration goals. The needs for the project include both pre-action environmental and regulatory reviews as well as pre- and post-restoration monitoring to assess actions and guide management.

5.5.1 Pre-Restoration Monitoring To Inventory Existing Conditions To Facilitate Environmental Review And Permitting

Project review is required under the California Environmental Quality Act (CEQA) and for necessary permitting under the federal and state Endangered Species Acts (ESA, CESA), the Clean Water Act (CWA), the California Fish & Game Code, the California Coastal Act, and the Porter-Cologne Act. To support these review processes, it will be necessary to fully document resources that will be affected by the restoration activities. Much of the habitat and wetland mapping has been completed through the restoration planning process, however, additional biological data collection are necessary in two primary areas as specified below.

General Biological Resource Inventories

While Malibu Lagoon has been extensively studied over the past two decades, the most comprehensive inventories of species resources within the identified habitats are now ten years old and information cannot be relied on at this time to support a current evaluation of the potential effects of the restoration on existing communities. To provide a current baseline biological report and impact assessment, it will be necessary to conduct updated surveys of the plants, fish, and wildlife resources of the lagoon system. To a great extent, the work may be limited to verification and updates of data already collected and reported in prior studies. Using the habitat mapping work completed in 2004 as a baseline, resource inventories should identify species dominating the delimited habitats. These data will be important to evaluating the probable effects of project implementation on the biological resources of the lagoon. Surveys to be conducted should include the following:

1. Floristic Inventory – A one time floristic inventory should be conducted during the spring/early summer season (spring/summer seasons) to document the plants present within the lagoon environment and to link plants to previously mapped vegetation communities. The survey should be conducted by a qualified field botanist.
2. Fish Community Inventory – Species present within the lagoon are not anticipated to differ substantially from those detected during the completion of the Ambrose et al. 1995 studies. For this reason, no further broad scale surveys are warranted. However, see section on threatened and endangered species.
3. Avian Community Inventory – Resource inventory surveys of the lagoon that should be conducted to support environmental review and permitting should include a seasonal

survey of avian species that results in an inventory and count of species present as well as an identification of species use of the represented habitats. A comprehensive species list for the lagoon has previously been prepared and extensive surveys have been conducted (Garrett field notes 1980-1996, Manion and Dillingham 1989). Ambrose et al. (2005) began the process of linking avian guilds to habitats. A knowledgeable ornithologist with extensive experience at Malibu Lagoon should be retained to prepare a comprehensive avian species matrix that indicates important habitat usage, frequency of occurrence, and relative abundance. Combined with an updated survey, the habitat utilization matrix is expected to provide adequate information to support environmental assessments of the project effects on birds.

4. Mammalian Community Inventory – Comments have been made by the public regarding the general lack of information available regarding the mammalian fauna of Malibu Lagoon. Based on a concern that the inventories and environmental impact assessments be complete, it is recommended that a spring/summer season mammalian survey be conducted that would focus on identification of small mammal fauna that may exist in and around the lagoon. A multiple night small mammal trapping and bait station trackplate program should be implemented within all vegetated habitats represented in the lagoon. In addition, a survey should be conducted to identify mammal signs including scat and tracks for the purposes of developing an inventory of mammals present by represented habitat types.
5. Herpetofauna Surveys – Prior surveys of the lagoon have not focused on the presence of reptiles and amphibians. Given the perennial nature of Malibu Creek there is some potential for the lower creek and upper lagoon to support sensitive herpetofauna including southwestern arroyo toad, western pond turtle, and two striped garter snake. To determine the status of these species as well as more common reptiles and amphibians, it is recommended that a spring/summer season survey be conducted. This work could be conducted coincident with mammalian surveys and could employ the use of visual surveys, seining of quiescent waters, drift fences and pitfall traps, as well as nocturnal surveys for auditory and visual detection. Surveys should be conducted over multiple nights during warm periods. Depending upon rain events and temperature, it may be necessary to conduct surveys during spring as well as summer to effectively detect all sensitive species.
6. Terrestrial Entomological Surveys – Comprehensive surveys of terrestrial invertebrate fauna present at the lagoon would be costly and not particularly useful in analyzing the restoration effort effects. However, there are a number of sensitive species that are found in the region with potential to occur at the lagoon. These include salt marsh skipper, other lepidoptera, and various Cicindelid beetles. These species are best inventoried during the warm spring or early summer months during visual surveys of the site. Nocturnal surveys may be conducted using attractant techniques such as black lights, however, it is not expected that such methods will be required.

Threatened & Endangered Species Surveys

Malibu Lagoon is known to support year-round presence of tidewater gobies, seasonal presence of southern steelhead, and seasonal use by California least tern and western snowy plover. While the seasonal presence and habitat use around the lagoon is well known for listed avian

species, the habitat utilization of the lagoon by listed fish is less well known. In order to assess the potential for adverse effects and to minimize impacts to listed fish resulting from construction activities, a focused investigation should be undertaken to assess the distribution of tidewater gobies and steelhead in the lagoon. Updated surveys should be implemented during open and closed lagoon conditions. The surveys should include widespread seining of the lagoon to identify high use areas by gobies and to determine the presence or absence of southern steelhead throughout the year or the time period available prior to completion of the CEQA document. The results of these surveys should be used to plan construction phasing and impact minimization measures. Results should also be incorporated into the assessment of environmental impacts under CEQA and in the development of information necessary to support Endangered Species Act consultation.

5.5.2 Pre- and Post-Restoration Monitoring to Evaluate Restoration Success

Below are the monitoring parameters that have been selected to quantitatively address the ability of the restoration program progress towards the physical, chemical and biological goals of this project outlined in Section 5.4. Sampling protocols, sampling schedules and specific locations are provided below. These protocols are to be used as a guide for implementation of the monitoring program and may be subject to change. In addition to specific protocols, the frequency of monitoring is likely to change as it is anticipated to be more frequent immediately following restoration to detect short term recovery and then become less frequent to detect long-term changes.

Monitoring site locations are suggested in this document, but their exact locations may need to be modified over time. The goal of selecting final monitoring sites is to identify functionally equivalent sites for pre- and post-restoration monitoring. Planning of sites must demonstrate some functional similarity based on physical/chemical/biological rationale to allow the most reliable comparisons of data in the future.

The most cost effective, robust and reliable monitoring program would be best served under the oversight and with the expertise of professional personnel. Consistency and repeatability are the keys to useful monitoring data collection in the field. Data management and analysis should be performed by trained professionals who can provide insight to the nuances, trends and interpretation of the data.

It is anticipated that training of agency monitoring staff by professionals may be useful. The professionals will assist to establish the data management and database format techniques to be used for each these parameters. Training can also include establishing data recording, data management and procedures to provide for organized and consistent field data. The monitoring will require a strong commitment by the selected agency and personnel to render it effective. Protocols for each monitoring parameter are provided below.

Physical

Physical components to be monitored include those items described below.

Cross-Section Monitoring

For cross-section monitoring, four (4) permanent and repeatable cross-section locations will be monitored bi-annually during pre and post restoration. Horizontal and vertical locations of cross section end points will be fixed by monuments. Changes in bathymetry at 4 selected locations will be monitored over time. Estimates of sediment volume scour or deposition can be made from data, and cross sections can be used with water budget data to calculate inflowing/outflowing channel velocities through cross-sectional area. Cross-section monitoring should be performed at the end of the rainy season during open conditions (~April) and again prior to the wet season (~September).

Pre-restoration preparation: Semi-permanent monuments will be established by qualified staff with fence posts and eyelets at locations indicated in Table 7 and surveyed into an existing topographic map. Cross-sections will be obtained by attaching a taught survey tape to the monuments and recording channel depth and water elevation at equal increments across cross section to collect at least 20 data points. Field personnel must be prepared with hip waders or inflatable boat depending upon water level conditions.

Pre-restoration monitoring: Monitoring will continue following the sampling schedule until restoration construction ensues. Data will be recorded in a field notebook and entered into Microsoft Excel in a database format developed by the qualified staff.

Post-Restoration monitoring: Following construction, qualified staff will establish permanent monuments at the restored lagoon locations indicated in Table 7 and surveyed for vertical and horizontal locations. The monuments should be tied to the updated topographic survey once conducted. Monitoring techniques remain the same as above.

Continuous Water Surface Elevation And Flow Velocity Monitoring

Continuous water surface elevation monitoring will be accomplished by using meters. Deployable water quality instruments will be installed and maintained at 3 locations within Malibu Lagoon. The recommended instruments are equipped with water pressure transducers to allow continues water depth measurements. The recommended instruments are used to measure additional water quality parameters. An example instrument is shown in Figures 17 and 18.

Water surface elevation monitoring will be used for various purposes, but one use is to estimate tidal flow velocity within channels. This method requires calculations to quantify velocities. Alternatively, a separate instrument can also be deployed to directly measure flow velocities and eliminate the need for the calculation. Both approaches are described below.

The parameters above (cross-sections and continuous water surface elevation monitoring) will allow the assessment of the spatial distribution of circulation and an evaluation of the circulation

benefit restoration efforts provided during tidally-dominated conditions. The continuous depth data can be used to create a rating curve that relates the water depth to lagoon volume for both existing and anticipated restored conditions. Time series changes in water volume can be used to create a simple water budget of the lagoon. The water budget data will be applied to:

1. Track the water volume changes over time (depth data) related to the tidal cycle at the mouth (WXTides or some other tidal time series program) and evaluate tidal influence on lagoon circulation during tidally dominated conditions; and
2. Create a time series of estimated flow velocities at channel cross-section locations using water volume changes over time. These data, combined with the water quality time series from the data loggers, will allow for the quantification of the critical tidal elevation that induces flushing of the western restored areas and the frequency of that tidal elevation.

During closed lagoon conditions, the continuous depth data will be used to determine the lagoon volume filling rates, equilibrium lagoon water volumes and detailed data on sandbar dynamics. This information can be evaluated with tidal variations and surface water inflow hydrology to quantify specific parameters of the lagoon water budget during closed conditions.

Alternatively, a continuously-recording velocity meter can be installed near the downstream end of the western arm to record tidal flow currents. The type of meter can vary, but a Doppler-type of technology is recommended for semi-permanent deployment for the annual dry season.

Pre-restoration preparation: The qualified staffs will determine the most appropriate instrumentation necessary to collect in-situ velocity measurements. Options include manual pigmy meters or digital velocity meters.

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Final Malibu Lagoon Restoration and Enhancement Plan	The YSI 600XLM	**Figure 17**

Medium:	Fresh, sea or polluted water
Temperature:	-5 to +45°C
Computer interface:	RS232, SDI 12
Logging Memory:	384K, logs 150,000 readings
Software:	EcoWatch for WIndows 3.1 included: PC compatible, 3.4" disk drive, 386 processor or better, running Windows 3.1 or later, 4 MB RAM minimum, English and French
Size:	1.7" OD x 21.3" long (4.32 x 54.1cm)
Weight with batteries:	1.5 lbs (0.7 kg)
Internal power supply:	4 AA-size alkaline cells
External power supply:	12 VDC

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Final Malibu Lagoon Restoration and Enhancement Plan	YSI 600XLM Specifications	**Figure 18**

Pre-restoration monitoring: Monitoring locations will correspond with the cross-section locations as presented in Table 7. Exact timing of each sampling will be determined by the qualified staff, taking into consideration, tides, stream discharge, weather, sand bar status and other relevant concerns. Velocity measurements are taken only during open sandbar conditions and during a falling tide. Velocity measurements will be collected at 4 equal distances across the cross section. Each location will include 3 measurements to quantify the vertical variations in velocity within the water column. The water depth at each site will be measured, divided by 3 and velocity measurements will be conduced in the middle of each third. Data will be recorded in a field notebook and entered into Microsoft Excel in a database format developed by the qualified staff.

Alternatively, direct flow velocity monitoring can be done continuously using a Doppler technology meter such as the Sontec Argonaut shown in Figures 19 and 20, and described in Appendix C.

Post-restoration monitoring: Monitoring locations will correspond with the cross-section locations in the restored lagoon as presented in Table 7. Field techniques will remain the same as used above.

Aerial Topographic Surveys

For aerial topographic surveys, surveys should be recorded to address lagoon circulation and sediment aggradation/degradation dynamics over the long-term. Their timing is immediately post-construction, then at 2.5 years post-construction, 5 years post-construction, 10 years post-construction, and every 10 years thereafter into perpetuity.

Pre-restoration preparation: No pre-restoration preparation is need as that was already completed for the Feasibility Study in 2004.

Pre-restoration monitoring: This may already be covered with the 2004 data. If construction occurs very soon (close to 2005) without significant changes on-site, rely on 2004 data. If changes occur such as parking lot installation ahead of other construction, and/or construction does not occur until 2010, then do the survey immediately pre-construction.

Post-restoration monitoring: Perform the survey immediately post-construction, then at 2.5 years post-construction, 5 years post-construction, 10 years post-construction, and every 10 years thereafter into perpetuity. Perform an aerial topographic survey at low tide in the Spring season of the identified year. If photographed in color, the aerial image may be useful for vegetation mapping as well. Hire a surveyor to perform the entire project. They set ground survey markers and fly over the site to create a topographic map from the aerial for dry land areas. Areas covered by water will require standard surveying of points by a crew in a boat or wading. More accurate estimates of sediment volume scour or deposition can be made from data for longer-time periods to identify trends in accretion or erosion. The resolution of the survey should be at 1 foot contour intervals, with points accurate to ¼ of foot.

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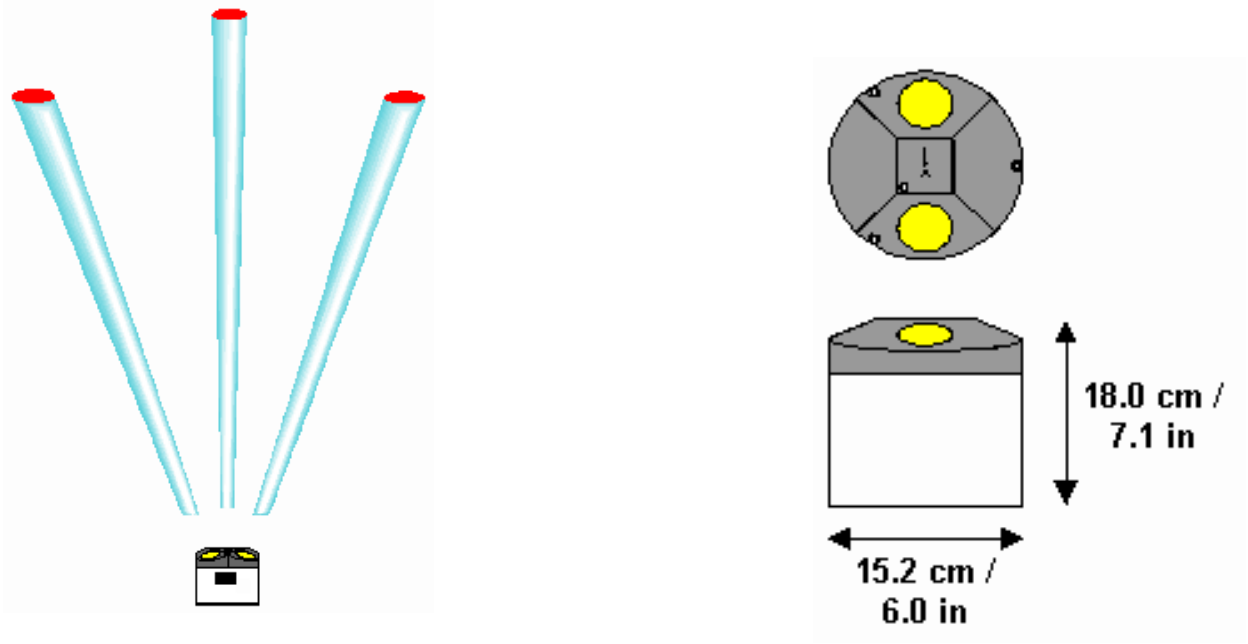
Final Malibu Lagoon Restoration and Enhancement Plan	The Argonaut-SL	**Figure 19**



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Final Malibu Lagoon Restoration and Enhancement Plan	The Argonaut SL in Concept	**Figure 20**

It may also be useful to perform a response survey immediately following severe storm flood events greater than the 25-year storm as determined by flow measurements from the Malibu Creek gage.

The survey should be conducted by a professional team to ensure surveys are repeatable over time. The first survey is the most expensive at nearly $20,000, because all survey monuments need to be established. All subsequent surveys are lower, at nearly $10,000. The costs are lower if clear water allows visual assessment of the lagoon bed thus reducing the need for ground shots.

Analysis of the change in sediment volumes throughout the site is to be done and should cost ~$5,000 for a qualified individual to calculate the volume changes along cross-sections and interpret the data.

Sediment Sampling

Surface sediment samples (top 0-2 cm) will be collected bi-annually (end of April and end of September) at 4 locations within the lagoon (3 cross-section locations in the West Arm and one within the main channel) to evaluate the spatial circulation dynamics of the existing and restored lagoon. Sediment samples will be submitted to a laboratory for testing of grain size distribution and total organic carbon (TOC), total nitrogen (TN) and total phosphorous (TP) concentrations. The seasonal and temporal sediment sampling results will allow the evaluation of the storm flow capability to scour organic material from the previous summer, the distribution of storm flow deposition of sand and relative supply of nutrients emanating from the sediments. The results from the sediment sampling will be used to evaluate the success of the restoration and help guide adaptive management decisions.

Pre-restoration preparation: Qualified staff will coordinate sampling handling procedures and select the analytical facility to perform the grain size and nutrient analyses. Qualified staff will coordinate sample container obtainment based on analytical facility needs. A sampling apparatus will be constructed to allow sampling during times of site inundation. All samples will be analyzed for grain size distribution in order to obtain the following size distribution information for each sample:

- Greater than Sand: >2.0 mm
- Sand: .05 to 2.0 mm in diameter
- Silt: .002 to 0.5 mm in diameter
- Clay: less then .002 mm in diameter
- Average size (d50) (um)

Sediment samples will also be analyzed for total nitrogen, total organic carbon and total phosphorous concentrations.

Pre-restoration monitoring: The 4 sediment sampling transects are indicated in Table 7 and correspond with the cross-section sites. In order to eliminate variability, a minimum of 5 sediment samples will be collected at each transect, sampling distinct habitat types (bank, bar, channel thalweg, and mudflat), and should be collected to represent the variation within the cross section. Sample locations should be marked by GPS and resampled at each sampling event regardless of inundation regime. Data from the analytical laboratory should be submitted directly to the qualified staff. Sampling should continue according to the schedule in Table 7 until construction commences.

Post-restoration monitoring: Following construction, sediment sampling should ensue at the restored sites and schedule presented in Table 7.

Photographic Point Time Series

Photographic points will be established at each of the terrestrial monitoring locations depicted in Figure 16. The direction and orientation of the photographs will remain consistent throughout the pre and post monitoring program. Photographs will be taken seasonally (4 times per year) and a photograph log will be maintained to qualitatively evaluate the visual changes within the lagoon over time. Information concerning climate, sandbar conditions, stream flow discharge, tidal heights, etc, will be noted along with date and time of each site photograph.

Pre-restoration preparation: The qualified staff and selected monitoring personnel will preview the site and establish the specific direction of each photographic point at the stations indicated in Figure 16 and Table 7. The qualified staff will generate a map to indicate the specific locations and directions of the photographic points. A photo logging, labeling and storage system will be developed by the qualified staff.

Pre-restoration monitoring: The photographic points will be monitored by the same personnel who maintain the continuous water quality instruments every 30-45 days.

Post-restoration monitoring: The photographic points will be monitored by the same personnel who maintain the continuous water quality instruments every 30-45 days.

Chemical

The following parameters will be monitored by trained professionals selected by the qualified staff team. The following monitoring requires a significant amount of specialized field equipment that most aquatic and habitat qualified staffs possess or should obtain to properly perform the monitoring requirements of this plan. Table 8 provides a list of the required equipment to perform monitoring components and the estimated associated costs.

Continuous Ancillary Water Quality (Water Temperature, DO, Salinity, Conductivity, pH, ORP)

The continuous water quality monitoring provides a number of benefits to accurately assess the dynamic nature of Malibu Lagoon. Due to the cost of these instruments and the seasonal water quality dynamics of lagoon environments, it may not be prudent to have them deployed during

rainfall/runoff events (November through March) to reduce the probability of instrument loss. The instruments should be deployed and maintained continuously each year from April up until the first significant runoff event of the season. During tidally-dominated conditions, dissolved oxygen, temperature and salinity data collection at strategic locations will identify the extent of penetration of saline, oxygenated, and cooler (oceanic) water exchange in the western arm sites at various tidal elevations and cycles. The ancillary water quality data will also provide information on the biogeochemical cycling as a function of climate and season during open conditions. Deployment during open conditions must be done considering their potential for vandalism and/or theft. They must be secured and optimally be screened from sight, and possibly maintained covertly to minimize the potential for vandalism and/or theft.

During closed conditions, measurements of dissolved oxygen, water temperature, ORP and salinity in the bottom water column will be collected over the duration of closure at 3 locations, one in the main channel and two in the western arm area. To control for inter-annual variability, data in the restored areas will be compared to the main channel conditions as well as baseline (pre-restoration) conditions at the functionally similar sites. Water temperature is an indication of solar exposure and water circulation. Minimum and daily variation of ORP and DO values are direct proxies for biogeochemical cycling and aquatic habitat conditions. DO is significantly influenced by primary production and respiration rates and will provide data regarding the seasonal and spatial magnitude of eutrophic conditions. ORP is the ability of water to oxidize or reduce. The ORP is measured in millivolts (mV), with positive values indicating an oxidizing behavior and negative values indicating a reducing behavior. When DO values get very low, the relative negativity of ORP in an aquatic environment provides insight on the magnitude of anaerobic (reducing) conditions. Frequency and duration of critical conditions such as low dissolved oxygen levels, ORP values, and elevated water temperatures will be evaluated to assess restoration performance. Measurement of surface water temperatures at the automated sites will provide maximum daily surface temperatures and be compared with bottom water temperature time series to map the degree of thermal stratification in 3 locations over time.

Pre-restoration preparation: Additional equipment is required to perform and maintain continuous monitoring equipment, including 3 YSI 600XLM data loggers shown in Figures 17 and 18 and described in Appendix B, pH/ORP probes, calibration solutions, HoBo temperature loggers and hardware for proper and secure deployment. Equipment will be purchased with the intent that State Parks will need all necessary cables, software, calibration solutions and other components to maintain the instruments on a regular basis. State Parks will need a field laptop or palm pilot to download data files on site. Qualified staff will design and install the equipment hardware within the lagoon for proper instrumentation deployment. The qualified staff will remove the equipment hardware prior to construction, and store for reinstallation following restoration activities. One or more units may remain during construction if the unit does not impact construction and may provide valuable construction water quality monitoring data. The qualified staff will train the designated staff personnel on instrument maintenance, calibration, data management and storage.

Pre-restoration monitoring: The YSI 600XLM data loggers must be removed and serviced every 30-45 days for proper operation. The HoBo temperature loggers may need to be serviced every

6 months to ensure proper operation. Following the initial training by the qualified staff, maintenance of the automated instrumentation will be the responsibility of the staff personnel.

Post-restoration monitoring: Following construction, instruments will be reinstalled in the new locations designated in Table 7 by the qualified staff. The maintenance of the instruments post-construction will remain the responsibility of the staff personnel. Data sharing from the staff to the qualified staff will follow strict procedures to ensure all data is provided electronically to the qualified staff over the course of the monitoring.

Manual Water Quality Sampling

Vertical Profiles

Bi-annual vertical profiles (0.5 foot intervals) of ancillary water quality parameters (DO, temperature, pH, salinity) at 6 sites will allow the expansion of the spatial representation of the continuous data loggers in addition to providing a QA/QC method to ground truth the continuous datasets. Turbidity will be measured with a turbidity meter. This information complements the vertical profile, nutrient and chlorophyll sampling.

Pre-restoration preparation: Qualified staff will obtain the necessary equipment to perform vertical profile measurements of DO, temperature, pH, and salinity as shown in Table 8. Field data sheets and a data management database will be developed by the qualified staff to ensure proper data maintenance and field collection.

Pre-restoration monitoring : The location and timing of vertical profile sampling is provided in Table 7. Vertical profiles should be conducted at that same time of day for each monitoring event and efforts should be made to correlate the time of day to an outgoing tide during open sandbar conditions. At each of the 6 stations, ancillary water chemistry parameters (DO, temperature, salinity, and conductivity) are collected with a hand held multi-parameter probe from a floating platform (e.g., kayak, boat, inflatable raft, paddleboard) at 0.5 foot intervals by securing a weight to the YSI probe and measuring tape-marked depths. With every vertical profile, turbidity will be measured using a turbidity meter. Data sheets should used and data should be entered into the digital database upon return to the office.

Post-restoration monitoring: The same procedures will be conducted at the restored monitoring sites indicated on Table 7.

Surface And Bottom Water Nutrient Sampling

Bi-annual surface water (1 foot below surface) and bottom water samples will be collected at the 6 vertical profile sites. Surface water samples will be analyzed for nitrogen (N) and phosphorous (P) species and chlorophyll a. Bottom water samples will be analyzed for the suite of primary nutrient only (N and P). The surface water sampling will provide a dataset to evaluate the concentrations of total and biological available fractions of nutrients required for primary production. Surface water chlorophyll data will provide an indication of the primary producer metabolic inputs from phytoplankton and algal communities.

The establishment of the temporal and spatial sampling protocols will allow continual monitoring of the water quality benefits of future source control efforts on the nutrient conditions within the Malibu Lagoon. The collection and evaluation of bottom water nutrient levels will allow a quantification of the degree of biogeochemical cycling occurring within the lagoon and additional data regarding the magnitude of surface sediment regeneration of nutrients. The seasonal and long term nutrient data will provide invaluable information on the long-term restoration of water quality within the Malibu Lagoon.

Pre-restoration preparation: Qualified staff will obtain the necessary equipment to conduct water quality monitoring Table 8. The vertical profile data base will include nutrient and chlorophyll sampling results at each station during each monitoring effort to ensure proper data management.

Pre-restoration monitoring: Surface water nutrient sample collection will be concurrent with vertical profiles at all 6 stations indicated in Table 7. Bottles will either be purchased or obtained from the analytical laboratory. Bottles are triple-rinsed instream, surface sample collected (do not fill completely), labeled with station, date and other relevant information and put on ice immediately until filtered or delivered to the laboratory. Samples must be filtered or delivered to the laboratory within 3 hours of collection. If filtered on site, personnel should use a 0.45 uM filter, Masterflex tubing, battery operated pump, to transfer the filtered sample to a pre-rinsed 30 ml bottles (or whatever volume is recommended by the analytical facility). Filtered samples are stored in a freezer until delivery to lab. Holding times of frozen filtered samples can be up to 28 days from date of collection. Chain of custody documenting sample label, date/time collected, and sample identification will accompany samples to the laboratory. At least one field replicate will be collected during each sampling effort to quantify field sampling precision. At each sampling location bottom water samples should be collected using a Van Dorn sampler and submitted for nutrient analyses. Samples are to be filtered and stored, or placed on ice and delivered to the laboratory in the same manner as surface samples.

All water samples should be submitted to an analytical laboratory for the following analyses:

- Total dissolved organic nitrogen (TKN);
- Dissolved nitrate (NO3-);
- Dissolve nitrite (NO2-);
- Dissolved ammonia (NH4+);
- Total dissolved phosphorous (TP);
- Soluble reactive phosphorous (SRP).

Additional surface water samples should be collected at each site in 250 mL amber bottles and submitted for chlorophyll a concentrations. Samples should be immediately placed on ice following collection. Samples must either be submitted to the laboratory with 3 hours or collection or filtered on-site. If filtered by field personnel, all filtration should occur away from direct sunlight. Watman 0.45 uM 25mm glass microfiber filters are placed on a screen using forceps. A carefully measured amount of sample (using a graduated cylinder) is added to a

funnel filtration system designed with a hand pump to create a vacuum and slowly pull the sample through the filter. Following filtration, the volume of sample filtered is documented and the filter is removed with forceps and placed in aluminum foil for labeling (date, time, site, volume filtered) and storage (frozen at < 4^{o}C until analysis within 28 days).

Post-restoration monitoring: The same procedures will be conducted at the restored monitoring sites indicated on Table 7.

Biological

Biological Components

SAV/Algal Percent Cover Monitoring

Submerged aquatic vegetation (SAV) and macroalgae are to be monitored at each of the non-marsh sampling stations (anticipated to include Stations 1-6 and 8). Monitoring shall be conducted during the months of April and September of each year preceding as well as for a period of five years post restoration. Each station will be represented by three replicate $1m^2$ square enclosure randomly placed within 10 meters of the station coordinates. The percent algal and SAV covers will be individually estimated at each station. Depth to surface of SAV and location of algal in water column should be noted. Samples should be collected of each species observed, properly labeled and identified.

Pre-restoration preparation: Qualified staff will prepare field data sheets and photo identification cards to be completed and used during field monitoring. Qualified staff will prepare the database format to maintain field data in digital form.

Pre-restoration monitoring: SAV/algal surveys will be conducted in the locations according to the schedule presented in Table 7.

Post-restoration monitoring: The same procedures will be conducted at the restored monitoring sites indicated on Table 7.

Habitat/Vegetation

Permanent Transect Monitoring Program

At each Site 1-9, a baseline transect will be established perpendicular to the shoreline such that it crosses the maximum vertical range beginning at or near the identified station location. Points will be established along each baseline within each habitat zone represented on the transect. At each point a 20-meter (m) fiberglass measuring tape shall be extended away from the baseline, parallel to the shoreline. Transects will be marked with PVC stakes at the beginning of the survey program and coordinates will be obtained using a Differential GPS to aid in stake relocation or replacement if necessary during the course of monitoring.

Along each transect, the percent cover of plant species and bare ground/open water shall be recorded. Cover of individual plant species shall be recorded for each meter along the 20-meter transect, and percent cover of plant species and bare ground/open water will be determined using the line-intercept method (PERL 1990). Plants and bare ground/open water are to be recorded only if a part of the plant or bare space falls underneath the visual line of the fiberglass measuring tape. The minimum unit of intercept recorded shall be one decimeter. Often, percent cover along a transect will exceed 100% due to overlapping canopy layers.

If resources are available, soil and/or water salinity shall also be determined along each sampling transect. Soil salinity are to be estimated using a 10-centimeter (cm) soil core. Water is to be filtered from soils using a syringe containing two No. 1 filter papers. Interstitial soil water will be pressed onto a salinity refractometer and salinity will be estimated to the nearest part per thousand (ppt). If a transect occurred in an open water area, water salinity shall be measured instead with the salinity refractometer. A 200 milliliter (ml) sediment sample is to be randomly collected along each transect, transported to the laboratory, and analyzed for grain size distribution and total organic carbon (TOC).

Vegetation Mapping: Utilization of Aerial Photography and Field Truthing

In order to facilitate vegetation mapping, as well as the long-term vegetation trend analyses, color infrared (CIR) aerial photography is to be used. The photography products provide a base-map for ongoing field studies, facilitate vegetation community and habitat association classification, and allow for analysis of change in each vegetation community. The CIR photography is to be acquired during flights conducted at low tides during open lagoon conditions in the later spring months. This allows photography of as much exposed intertidal habitat as possible. The imagery is to be acquired each year or at other regular intervals (such as every five to ten years) during the same approximate seasonal and tidal conditions to allow for a comparison of any changes that occur within the lagoon and provide the basis for long-term vegetation trend analysis. The aerial imagery can be acquired as part of the aerial survey for topography/bathymetry previously discussed. Both efforts should be combined to reduce costs and maximize effectiveness.

Using the aerial photograph and field truthing, the conditions within the lagoon should be mapped in a spatially rectified and consistent coordinate system using GIS to produce year to year maps of the lagoon and to identify any progressive changes in lagoon conditions.

Benthos

Benthic surveys are to be conducted at Stations 1 through 9. Station profiles are outlined as follows in Table 6 below.

Table 6 – Benthic Survey Station Profiles

STATION	TARGET ELEVATION (FEET MSL)	DESCRIPTION
1	0 feet or lower channel bottom	Upper main lagoon
2	+1 feet or lower channel bottom	Upper slough channel
3	+2 feet	Mudflat – central bar
4	0 feet or lower channel bottom	Middle slough channel
5	+2 feet	Mudflat – western arm
6	-2 feet or lower channel bottom	Lower slough channel
7	+4 feet	Seasonally inundated marsh
8	0 feet or lower channel bottom	Lower main lagoon
9	+4 feet	Seasonally inundated marsh

Benthic sampling shall be conducted in August of each year in order to characterize communities at the most stressful period of the year. Sampling shall be undertaken annually preceding and following restoration. A differential GPS will be used to accurately locate sampling stations during each of the sampling efforts. Following restoration, it may be necessary to relocate stations slightly in order to maintain desired reference elevations and habitat type equivalency. Once station relocation is conducted, monitoring station locations should be maintained to the greatest extent practical to maintain habitat equivalency in sampling. Field crews must possess a valid California scientific collectors permit issued by the California Department of Fish & Game.

At each station, three replicate cores shall be collected along the station's sampling isobath using a large (15 cm) diameter corer pushed 15 cm into the sediment surface. An additional core shall be collected at each benthic station and shall be used for analysis of TOC, sediment grain size analysis, and TKN.

Each of the three benthic sample replicates shall be rinsed through a 1.0 mm sieve. Organisms from each sample shall be preserved in a buffered 10% formalin:seawater mixture, and transported to the laboratory. Between three and ten days, samples will be rinsed and transferred to 70% ethanol for laboratory taxonomic analysis and for long-term archival of samples. Following sample transfer to alcohol, all individuals in each replicate sample are to be identified

to the lowest practical taxonomic level (typically species) and then counted. The occurrence of nematodes, foraminiferans, and pelagic organisms not classified as infauna or which were too small to quantify shall be noted; however, these organisms are not to be quantified. The benthic community characterization shall principally be structured to provide an indication of the relative availability and abundance of infaunal and epifaunal organisms within the various regions of the lagoon and to provide a means to evaluate community profiles using such tools as a benthic response index (BRI).

Organisms shall be grouped by phylum and weighed to determine the wet weight biomass of each phylum in each replicate sample. Wet weight is to be determined by transferring organisms, including alcohol, onto a paper towel and blotted quickly to remove excess liquid from the animals. Organisms are then to be transferred to a tared weighing dish and weighed to the nearest 0.001g using an analytical balance. Samples shall be stored in 70% alcohol for future review.

Epibenthos

Epibenthic sampling shall be conducted coincident with fish communities studies described in the following section. The epibenthic invertebrate by-catch collected in the fish-sampling program will be identified and counted to characterize changes in the distribution, composition, and abundance of these organisms within the lagoon. For species that cannot be identified in the field, collections will be made for subsequent laboratory taxonomy. A voucher collection shall be prepared for invertebrate species. Collected and archived individuals shall be preserved in a 10% formalin:seawater mixture for 3 to 10 days prior to transfer to 70% ethanol for archival.

Pre-restoration preparation: The qualified staff will prepare field instructions, data sheets and site maps for the completion of field surveys. The qualified staff shall assist the volunteer field teams in the acquisition of appropriate sampling equipment and will train field teams in equipment use. Field survey teams shall be assembled from State Parks staff or local volunteers. Those participating in the taxonomic identification must be qualified to make accurate species identifications of most of the collected organisms to avoid large volumes of laboratory work.

Pre-restoration monitoring: The qualified staff will participate in a first survey event with staff and volunteers to establish survey protocols and resolve any unforeseen data collection or recording issues. Following a first field survey, staff and volunteers will conduct further surveys and will coordinate with the qualified staff as necessary to ensure consistent data collection methods are employed. For benthic samples and unidentifiable epibenthos, preserved samples shall be preserved in formalin, transferred to alcohol, and shipped to a qualified benthic laboratory to accomplish sorting, taxonomy and biomassing tasks.

Post-restoration monitoring: Following construction, staff and volunteers will continue annual field surveys for a period of five years and shall continue to use qualified benthic laboratory support services.

Fish Communities

Four fish sampling stations are to be established within Malibu Lagoon to characterizes fish communities in all aquatic environments represented in the system. A differential GPS will be used to accurately locate sampling stations during each of the sampling efforts. Fish sampling shall be undertaken at each station during daylight hours in late summer of each year. While sampling during other periods of the year would be expected to yield potentially different fish communities, the period of greatest concern relative to potential system stress is middle summer and as such this is the period of greatest interest in evaluating effectiveness of restoration efforts and necessity for implementation of adaptive management efforts. Implementation of the fish sampling efforts requires possession of a valid California scientific collectors permit issued by the California Department of Fish & Game and a California State Parks Department special use permit. In addition, given the reasonable expectation of capturing the federally-listed tidewater goby, a federal Endangered Species Act section 10(a) permit is required to conduct fish sampling in the lagoon.

Methods:

Using at least two 6 foot by 20 foot blocking nets, set up sampling areas in a minimum of 4 locations:

1. near the mouth of the lagoon
2. at the outlet of channel C
3. along the west edge near the bird peninsula
4. upstream of the PCH bridge on the west bank

A 4 foot by 10 foot 1/8th inch mesh minnow net affixed to 2 PVC poles is pulled across the water body, with the weighted bottom of the net kept firmly along the substrate, and the net angled to prevent fish from escaping. At the end of each pull, the net is raised and all fish species are counted, sized, and released. Distances for each seine pull vary depending on the locations. In creek channels, pulls start downstream and move upstream if the channel is small enough.

In addition to documenting numbers, size class, reproductive status of individuals and their characteristics, the location of the seine, direction of pull, distance seined, habitat characteristics are also noted.

At the start of each event, water quality observations are taken, including, depth, temperature, dissolved oxygen, salinity, pH, and in the case of creek channels, flow.

If a haul includes so many fish that keeping them in the net for counting is not possible, then buckets filled with water are used to sort each species before release.

Deliverables:

1. Excel spreadsheet will all field data
2. Report providing summary of all observations and recommendations for protecting the gobies during restoration implementation.
3. Map of seine locations and goby distribution areas.

4. Electronic copies of all materials.

Pre-restoration preparation: The qualified staff will prepare survey instructions, data sheets and site maps for the completion of field surveys. The qualified staff shall assist the volunteer or staff field teams in the acquisition of appropriate sampling equipment and will train field teams in equipment use. Field survey teams shall be assembled from State Parks staff or local volunteers.

Pre-restoration monitoring: The qualified staff will participate in a first survey event with staff and volunteers to establish survey protocols and resolve any unforeseen data collection or recording issues. Following a first field survey, staff and volunteers will conduct further surveys and will coordinate as necessary to ensure consistent data collection methods are employed.

Post-restoration monitoring: Following construction, staff and volunteers will continue field surveys for a period of five years.

Avian Communities

A qualified ornithologists shall conduct general avian surveys during the months of January, April, July, and October. If resources are available, more frequent survey should be conducted. In addition, it would be beneficial to set up a program that promotes an ongoing archive database of filed sightings. For example, Cornell Laboratory of Ornithology's "eBird" project may be used as a centralized database of Malibu Lagoon bird sightings (see www.ebird.org). It is also important to include specific breeding bird surveys such as those outlined in the Breeding Bird Atlas, standard territory mapping procedures, and Audubon/Association of Field Ornithologists "Breeding Bird Census" techniques.

For general surveys, the lagoon is to be surveyed on foot using binoculars and spotting scopes. The entire lagoon is to be broken into 4 geographic zones defined as the Western Arm, the Main Lagoon, the East Shore and the berm/beach. The lagoon is to be surveyed twice, on two consecutive days during each of the quarterly survey events to minimize the probability of missing any species that may have not been present or not observed on a particular day. Surveys typically occur in the early morning and can be completed in several hours at this site. The survey team walks the zone that they are assigned to observe. They are to use existing trails for completion of surveys and shall reverse the direction of travel between the two survey dates. Surveys during open lagoon periods shall be conducted at approximately mean sea level tidal elevations. Data collected included species and individual counts, time of day, activities of the birds (e.g., foraging, flying, resting, and courting), and habitats in which the birds occurred (open water [> 1 foot depth], shallow water [<1 foot depth], as well as habitat represented in the existing lagoon conditions or the restored conditions such as mudflat, sand beach, gravel shoals, salt marsh, brackish marsh, cattail/tule marsh, willow riparian, upland disturbed including landscaped park areas and hardscapes, and upland scrub.

The habitats utilized shall also be categorized as open shoreline, peninsulas, islands, and open water. Additional data collected shall include any factor affecting the behavior of birds, such as an injury or the presence of a predator. Weather conditions, including air temperature, wind

speed, wind direction, cloud cover, precipitation, and water level, shall also be recorded once each hour through the course of the surveys. A count or approximation of the number of human visitors on the beach on an hourly basis and direct disturbances should also be noted (e.g. unrestrained dogs on the beach or in the lagoon, rock-throwing children, etc.).

After each survey, the data shall be entered into a database for subsequent analyses. All habitat, behavioral, and distributional observations shall be used to analyze avian use of the lagoon environments. The average bird counts by species over the two day survey period as well as raw data shall be included in a report to evaluate avian abundance and density within the lagoon and represented habitats during the survey interval.

Pre-restoration preparation: The qualified staff will prepare survey instructions, data sheets and site maps for the completion of field surveys. Field survey teams shall be assembled from State Parks staff or local volunteers.

Pre-restoration monitoring: The qualified staff will participate in a first survey event with staff and volunteers to establish survey protocols and resolve any unforeseen data collection or recording issues. Following a first field survey, staff and/or volunteers will conduct further surveys and will coordinate with the qualified staff as necessary to ensure consistent data collection methods are employed.

Post-restoration monitoring: Following construction, staff and/or volunteers will continue a minimum of quarterly field surveys for a period of five years.

5.6 PARAMETERS EVALUATED TO FACILITATE ADAPTIVE MANAGEMENT

The Malibu Lagoon Restoration Monitoring Plan has been designed to provide a management mechanism by which to evaluate the success of the Restoration implementation with respect to the goals stated in section 5.4 and to improve specified components of Lagoon function. A robust evaluation requires consistent data collection parameters and associated techniques during existing and restored conditions to allow confident conclusions that measured differences are due to Lagoon physical, chemical and ecological improvement and not an artifact of sampling variability.

In theory, constraining all spatial and temporal variability to confidently attribute measured change to restoration efforts should be feasible, but in many instances the complexity and dynamic nature of the seasonal lagoon will leave many questions unanswered. An expansive restoration monitoring program, as the one developed herein, will provide a diverse breadth of site-specific physical, chemical and biological information to both improve our understanding of the ecological function of these complex systems, as well as providing quantitative data from which evaluations of restoration, enhancement and source control actions can be assessed well into the future.

Specific performance criteria to observe in post-restoration monitoring are provided below. Triggers and options for adaptive management are also included where appropriate, however, adaptive management options should not be constrained to those listed below.

Goal: Improved water circulation in restored areas over existing conditions.

Specific Lagoon Performance Criterion: The restoration effort expects that a tidal and hydrologic connection will be maintained between the western arm and main channel of the Lagoon. Development of a sand bar that isolates the western arms from the main channel should be removed as soon as feasible to restore intended water circulation. Continual occurrence of sandbar formation (3 times over a 6 year period) should signal the need for adaptive management alternatives and reevaluate lagoon hydrodynamics as a result of restoration.

Adaptive management may be needed to achieve and maintain desired lagoon circulation over time. Measurements of circulation and water quality parameters will indicate if the project is functioning as desired or if modifications are needed to improve the desired effect. Signals, or triggers, to indicate the need for adaptive management can vary from open to closed conditions.

Potential triggers for adaptive management that may be observable during open conditions are if:

- The west arm main channel closes off from the main lagoon by sedimentation, and/or
- Peak tidal flow velocity drops to less than 0.25 feet per second, and/or tide range drops to 1 foot during spring tides. This value is an estimate based on adequate tidal flushing measured at other sites (Carpinteria Marsh, Talbert Marsh, and Batiquitos Lagoon), and observations made at Malibu Lagoon in the summer of 2004 (M&N, 2005).

Potential adaptive management actions for open conditions include those listed below in order of preference:

- Do nothing and allow the entire lagoon to close and fill during summer, and monitor the natural breach the following fall season to identify if the sediment deposit is scoured; or
- Manually open the closure between the west lagoon and main lagoon with either hand-held equipment or larger earthmoving equipment such as a backhoe; and/or
- Create a connection to the main creek via an alternate path to route water through the West Arms to eventually breach the barrier to the main lagoon.

Potential triggers for adaptive management than may be observable during closed conditions include if:

- Water quality data indicate significant and persistent stratification of lagoon waters (either thermally or density driven, e.g., salinity differences) and indications of depressed bottom water DO and ORP values;
- Significant areas of algal mats form and persist for many days to weeks; and
- Lagoon stagnation is obvious and areas of the surface collect algal mats, debris, and scum.

Potential adaptive management actions for closed conditions include those listed below in order of preference:

- Create a connection to the main creek via an alternate path to route water through the West Arms; and/or
- Consider installing circulation devices to move water artificially as a last resort if watershed sources of nutrient persist and nutrient loading to the lagoon remains a problem.

Specific Lagoon Performance Criterion: Results from the hydrologic monitoring should indicate sustained sediment transport velocities to mobilize and expel fine grained sediments from the west arm sampling locations during sufficiently high flow events. Residence of mainly sand size particles in the channels of the west arm areas should be consistently observed at the sampling sites. Grain size distribution (percent sand in the sample and/or of the median grain size, D_{50}) at each sampling location should increase by 20% (based on the judgment of the qualified project ecologist/scientist) from baseline monitoring conditions. Grain size distribution in west arms should be compared to results from main channel sites and should not result in less than 80% sand relative to main channel results for the same sampling period (also as judged by the qualified project ecologist/scientist). As judged by the qualified project ecologist/scientist, adaptive management alternatives should be seriously considered if any one of the following is observed in the grain size data:

1. If any one site fails the grain size criteria above for 6 consecutive samplings (3 consecutive years);
2. If any one site in the west arm has less than 60% of the sand fraction of the main channel for 4 consecutive samplings (2 consecutive years); or
3. If the average of any transect in the west arm contains predominantly (>50%) clay and silt-sized particles (D_{50}<50 micrometers, um) for 4 consecutive sampling efforts (2 consecutive years).

Time series velocity estimates from the water budget and the cross-sectional changes over time should be evaluated in concert with the sediment grain size data to provide additional insight to the broader temporal, spatial and physical mechanisms potentially responsible for the system's circulation performance. The grain size distribution data (especially for early spring data) should be evaluated in light of the Malibu Creek hydrology and climatic conditions during the wet months of the year. Annual precipitation totals, timing and magnitude of peak stream flows and estimates of annual peak reoccurrence intervals will allow more informed comparisons of grain size distributions across various water years.

Specific Lagoon Performance Criterion: Results from continuous water quality monitoring at 3 strategic locations should indicate an increase of tidal mixing and exchange during tidally-dominated, open lagoon conditions. The degree of tidal influx on the water quality of the western arm areas should be thoroughly investigated. The time series DO, temperature, ORP and salinity data will be evaluated in concert with tidal elevation data to determine the critical tidal elevation necessary to introduce relatively nutrient poor, cooler, higher DO water to the west arm

locations. Although that tidal elevation may change over time, the intent is to identify a threshold tidal elevation condition that could be expected to promote flushing of the western arms that can be a benchmark over time. Significant changes in this threshold elevation (*e.g.*, by 50%) may signal significant changes occurring within the lagoon system.

The magnitude and frequency of observed water quality changes as a result of flushing should be linked to tidal elevations to improve the understanding of the existing and restoration hydrologic dynamics of Malibu Lagoon. At least 12 occurrences of DO, salinity, and water temperature differences during a flushing event (transition from low to high tide) should be recorded during tidally-dominated conditions each year and compared to both main channel results (monitoring station 1) for the same time period and with comparable data (same relative tidal flux) for pre- and post-restoration conditions.

As judged by the qualified project scientist, adaptive management should be considered if data described above indicate any of the following as measured by continuous water quality monitoring during open conditions:

1. 2 consecutive years where DO values do not increase in the bottom waters by an average of 20% at high tide relative to previous low tide values (over an 8-hour period) during maximum tidal elevations over 5 feet;
2. 2 consecutive years where minimum DO concentrations are more than 50% below those observed in the main channel during the same time periods during tidally-influenced conditions;
3. 2 consecutive years where overall DO concentrations do not show at least a 20% improvement during similar flushing events at the same site during restored, relative to existing conditions;
4. 2 consecutive years where average salinity values during tidal flushing events are less than 50% of the salinity observed in the main channel; and/or
5. 2 consecutive years where average bottom water/surface water temperature differences are more than 3 times greater than the gradients observed in the main channel.

The continuous water quality data record will provide numerous other comparisons of lagoon physical and chemical function during open conditions between existing and restored conditions, as well as spatially within the restored lagoon (main channel versus west arm sites). Standardizing the data for tidal variations will improve the validity of the comparisons.

Specific Lagoon Performance Criterion: Results from continuous water quality monitoring at 3 strategic locations should indicate an increase in water exchange (e.g., mixing, movement, aeration, internal turnover) during closed lagoon conditions. Time series of water quality parameters provide insight to biogeochemical conditions and function. Improvements should occur in bottom water DO and ORP levels in the restored lagoon over existing conditions, as well as reductions in surface water temperatures in the western arms due to increased wind mixing and surface water movement. Water quality during closed conditions should be evaluated by comparing the frequency and duration of minimum DO and ORP values.

Site data should be compared to both baseline conditions at the analogous sites, as well as the use of the main channel water quality data as a reference to compare to the west arm restored area. Since closed lagoon conditions are most likely to have the poorest water quality conditions due to the excessive nutrient loading from surrounding land uses, the expectations for water quality improvements during this time should be limited. In the short-term (first 3 years), a 20% improvement in the frequency, duration and magnitude of the minimum DO, minimum ORP and maximum surface water temperatures relative the main channel conditions is feasible. Over the long-term (with progressive source control improvements), more significant improvements in the Lagoon water quality is likely.

Specific Lagoon Performance Criterion: Sediment nutrient (nitrogen, N, and phosphorous, P) concentrations influence biological activity and ultimately the Lagoon water quality and ecological health. Restoration efforts are expected to increase surface sediment grain size distribution throughout the west Lagoon, thus directly reducing the supply of N and P to primary producers from the sediment reservoir. The sediment nutrient data will directly complement the grain size distribution data to assess the performance of the restoration to reduce the supply of N and P. Adaptive management should be considered if:

1. The N and P sediment concentrations at any particular site are not reduced relative to existing conditions in the mean of sediment samples from any transect in the west lagoon following 4 consecutive restored monitoring efforts (2 consecutive years); ideally reductions should approach 30% relative to existing sediment quality.

Specific Lagoon Performance Criterion: Wetland vegetation communities should attain a percent cover of native species of 50% within 3 years and 90% within 5 years of restoration, as measured at vegetated habitats during peak growing conditions (late spring/early summer) prior to summer closure. If these goals are not attained, targeted studies should be performed to determine why goals are not being met and devise adaptive management solutions to achieve goals.

Specific Lagoon Performance Criterion: The abundance and diversity of fish and wetland avian species shall not decrease following restoration. Although a short-term decrease may be expected due to construction related impacts, fish and avian species should be at commensurate pre-restoration levels within 3 years of restoration activities. If these goals are not attained, targeted studies should be performed to determine why goals are not being met and devise adaptive management solutions to achieve goals.

5.7 QUALITY ASSURANCE / QUALITY CONTROL

A quality assurance/quality control program shall be undertaken for all aspects of the investigations conducted to ensure accuracy in field data collection, laboratory analysis, and data management. This program shall include pre- and post- calibration of sampling probes, review of datasets and removal of suspect data based on *a priori* data acceptance guidelines, consistent labeling of samples in the field, archival of laboratory samples and development and use of voucher collections and chain of custody forms, adherence to holding time requirements and adopted standard protocols for performance of tests and subsampling.

All field and laboratory results are to be recorded on pre-printed data sheets along with collection location, time, gear type, sample number, replicate, and collectors. Whenever possible, samples are to be worked up in the field or immediately after sampling. Live specimens are then to be released back to the point of capture. Representative individuals that are difficult to identify shall be transported to the laboratory and identified utilizing field guides and a dissecting microscope. In the laboratory, the investigator, date of analysis, and sample parameters are again to be recorded on hard copy data sheets. A voucher collection of fish species shall be created for future reference. A master list of species collected and photograph identification cards shall be utilized in the field to determine which species should be added to the voucher collection. If a new or unknown species is captured, it shall be transported to the laboratory where it is to be preserved, labeled (with species name, date, time, and location of collection), and added to the voucher collection.

For taxonomic laboratories, after the initial laboratory sorting, a second party shall select 10% of the samples and re-sort them for accuracy. A sample sorting efficiency of 95% of total number of individuals shall be considered acceptable for each sample. If more than 5% of the organisms in a sample is missed during the initial sorting (i.e. less than a 95% sorting efficiency), samples shall be resorted. Taxonomic verifications shall be addressed through completion of an independent review by a second taxonomist.

Computer data entry shall be verified by comparing the number of lines of data entered against the field data sheets, filtering the data for unreasonable entries to available data fields, and through conducting a number of rapid plot comparison tests, such as length:weight ratios for fish, to search for spurious outliers in the data and potential entry errors.

TABLE 7 - Sampling Frequency and Locations

COMPONENT	DATA USE	DATA APPLICATION	FIELD PERSONNEL	PRE-RESTORATION FREQUENCY	SITES	POST RESTORATION FREQUENCY	SITES
CEQA MONITORING							
General Biological Resource Inventories (floral, fish, avian, mammalian, herpetological, entomological); Threatened and endangered species	Quantify existing project conditions to establish the project baseline for analysis of impacts from restoration	Assess pre-project conditions for environmental review and permitting	State parks staff and qualified professionals	Spring and summer seasons prior to preparation of the CEQA document and permitting	The entire lagoon south of PCH bridge	Not applicable	All 9 sites

COMPONENT	DATA USE	DATA APPLICATION	FIELD PERSONNEL	PRE-RESTORATION FREQUENCY	SITES	POST RESTORATION FREQUENCY	SITES
RESTORATION PERFORMANCE MONITORING							
PHYSICAL COMPONENTS							
HYDROLOGIC MONITORING							
Cross-section monitoring	1. Water budget calculations to evaluate tidal circulation (volume flux and velocity time series) used for water level management 2. Time series of channel stability 3. Estimates of lagoon aggradation / degradation over time (sediment quantity)	Baseline conditions, Restored conditions Facilitate adaptive management	Biannually by qualified staff, potential to train State Parks personnel to expand sampling resolution	At least twice per year (April/Sept); potentially monthly	4 sites - Sites 2, 4, 6, 7	At least twice per year in April/Sept; potentially monthly	4 sites - Sites 2, 4, 6, 7
Water level monitoring with continuous data loggers YSI 600XLM	1. Water budget calculations to evaluate tidal circulation (volume flux and velocity time series) 2. Time series of lagoon channel stability at key locations	Baseline conditions, Restored conditions Facilitate adaptive management	Trained by qualified staff, maintained by State Parks	April - Oct (30 min intervals) Instruments removed during storm flow conditions.	3 sites Sites 1, 2, 6	April - Oct (30 min intervals)	3 sites Sites 1, 2, 6

Velocity measurements	Manual instruments or in-situ instrumentation to calibrate velocity time series from water budget calculations	Baseline conditions, Restored conditions, model estimate calibration	Biannually by qualified staff, potential to train State Parks personnel to expand sampling resolution	At least 2x per year (April/Sept) potentially monthly	4 sites (corres-pond to cross-sections) Sites 2, 4, 6, 7	At least 2x per year (April/Sept)	4 sites (correspond to cross-section locations) Sites 2, 4, 6, 7
SEDIMENT QUALITY AND QUANTITY							
Sediment sampling for grain size, TOC, and TN and TP	1. Grain size distribution, infer circulation conditions both pre and post restoration 2. Evaluate seasonal sediment nutrient flux	Baseline conditions, Restored conditions Facilitate adaptive management	Bi-annually by qualified staff	2x per year April/Sept	4 sites (5 samples per transect) Sites 2, 4, 7, 8	2x per year April/Sept	4 sites (5 samples per transect) Sites 2, 4, 7, 8
Aerial Topographic Mapping	3. Sedimentation patterns and volumes throughout the lagoon	Baseline conditions, Restored conditions Facilitate adaptive management	Once every 5 to 10 years by a professional aerial survey firm	One time during low water conditions (spring)	Entire Lagoon south of Pacific Coast Highway	One time during low water conditions (spring)	Entire Lagoon south of Pacific Coast Highway

COMPONENT	DATA USE	DATA APPLICATION	FIELD PERSONNEL	PRE-RESTORATION FREQUENCY	SITES	POST RESTORATION FREQUENCY	SITES
CHEMICAL COMPONENTS							
WATER QUALITY							
Water level monitoring. Continuous data loggers YSI 600XLM	1. Daily and seasonal, min, max and variations (frequency, duration) of key water quality parameters (DO, water temp, ORP, pH and salinity). 2. Evaluate restoration impact on water quality conditions in very chemically dynamic system. 3. Tidal circulation. Daily and seasonal variations in dissolved oxygen, water temperature, salinity, pH, ORP as influenced by tidal cycles. 4. Closed lagoon water quality	Baseline conditions, Restored conditions Facilitate adaptive management	Trained by qualified staff, maintained by State Parks	April - Oct (30 min intervals)	3 sites Sites 1, 2, 6	April - Oct (30 min intervals)	3 sites Sites 1, 2, 6

Vertical Profiles (Ancillary parameters)	1. Expand the spatial (vertical in water column and horizontally throughout lagoon) representation of continuous water quality data. 2. Calibration of continuous monitoring equipment	Baseline conditions, Restored conditions Facilitate adaptive management	Bi-annually by qualified staff	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8
Nutrient sampling Surface and bottom water samples: TKN TP Dissolved species include: Nitrate Nitrite Ammonia Soluble reactive phosphorous	1. Evaluate the degree and extent of biogeochemical nutrient cycling occurring in Malibu Lagoon, pre and post restoration. 2. Begin a standardized long-term primary nutrient monitoring effort of specific constituents (N and P) for future watershed source control efforts.	Baseline conditions, Restored conditions. Establish long-term nutrient monitoring in lagoon (key components of long-term water quality)	Bi-annually by qualified staff	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8

Chlorophyll sampling	1. Evaluate primary productivity contribution of phytoplankton 2. Begin a standardized long-term chlorophyll monitoring effort to evaluate success of future watershed source control efforts.	Baseline conditions, Restored conditions. Establish long-term nutrient monitoring in lagoon (key components of long-term water quality)	Bi-annually by qualified staff	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8	2x per year April/Sept	6 sites Sites 1, 2, 4, 6, 7, 8
Surface water temperature monitoring (HoBo data loggers)	Tidal and closed lagoon circulation. 1. Daily and seasonal variations in surface water temperature as influence by local climate Time series of spatial lagoon differences in vertical water temperature gradients.	Baseline conditions, Restored conditions Facilitate adaptive management	Trained by qualified staff, maintained by State Parks	April - Oct (30 min intervals)	3 sites Sites 1, 2, 6	April - Oct (30 min intervals)	3 sites Sites 1, 2, 6

COMPONENT	DATA USE	DATA APPLICATION	FIELD PERSONNEL	PRE-RESTORATION FREQUENCY	SITES	POST RESTORATION FREQUENCY	SITES
BIOLOGICAL COMPONENTS							
SAV and Algal surveys	1. Mapping of seasonal and pre/post restoration distribution and species of fixed primary producer community 2. Evaluate quantitative changes in the coverage and biomass of SAV and algae during spring and mid-summer conditions	Baseline conditions, Restored conditions. Evaluate restoration success.	Bi-annually by qualified staff	2x per year April/Sept each year prior to restoration	7 sites Sites 1, 2, 3, 4, 5, 6, 8	2x per year April/Sept for the first 5 years following restoration	7 sites Sites 1, 2, 3, 4, 5, 6, 8

Vegetation/ habitat surveys	1. General survey of lagoon habitats to map habitat changes and record any unexpected or undesirable changes such as erosion or sedimentation zones. 2. Transect surveys along established transects to track vegetation change within each target habitat type. 3. Mapping using aerial photography with color infrared imagery	Baseline conditions, Restored conditions. Evaluate restoration success.	Annually by qualified staff	1 time per year during open lagoon conditions	Lagoon-wide habitat mapping with transect surveys performed at 9 sites Sites 1-9 in adjacent vegetated areas	1 time per year during open lagoon conditions for a period of 5 years following restoration	Lagoon-wide habitat mapping with transect surveys performed at 9 sites Sites 1-9 in adjacent vegetated areas
Benthos	Replicated cores taken at monitoring sites throughout the lagoon to track changes in benthic infauna from pre- to post-restoration	Baseline conditions, Restored conditions. Evaluate restoration success.	Annually by staff and/or volunteers with external taxonomic lab. services	1 time per year during September	Sites 1-9 in adjacent vegetated areas	1 time per year during September for a period of 5 years following restoration	Sites 1-9 in adjacent vegetated areas
Fish and Epibenthos	Replicated beach seine sampling at submerged stations throughout the lagoon to track changes in fish and epibenthos diversity, abundance, and distribution patterns pre- to post-restoration	Baseline conditions, Restored conditions. Evaluate restoration success.	Annually by staff and/or volunteers with external taxonomic lab. support as necessary	1 time per year during September	5 sites Sites 1, 2, 4, 6, and 8	1 time per year during September for a period of 5 years following restoration	5 sites Sites 1, 2, 4, 6, and 8

Avian	Two day quarterly surveys of lagoon avifauna focusing on bird use of represented habitat areas.	Baseline conditions, Restored conditions. Evaluate restoration success.	Quarterly by staff/and or volunteers (or monthly with use of volunteer database)	Surveys conducted in January, April, July, and October	Lagoon-wide	Surveys conducted in January, April, July, and October for a period of 5 years following restoration	Lagoon-wide

The most cost-effective and reliable monitoring program will rely primarily on seasonal sampling by the qualified staff or hired professionals. Hired professionals may own much of the field and additional monitoring equipment necessary to perform all aspects of the bi-annual monitoring components, which would be a significant cost savings for the project to not have to equip State Parks with extensive monitoring equipment. Hired professionals may also be appropriate to perform more specialized sampling efforts that include biannual vertical profiles, nutrient, chlorophyll, and phytoplankton sampling, sediment sampling and biological components. This monitoring approach would allow State Parks to participate in key elements of data collection, yet ensure detailed monitoring data is consistently collected from well-trained field professionals.

Table 8 – Necessary Monitoring Equipment Summary and Estimated Costs

EQUIPMENT	AMOUNT NEEDED	ESTIMATED PURCHASE COST
Stadia Rod	1	$175
Survey tape	1	$75
Velocity meter	1	$11,000 (possible rental)
Station monument hardware	1	$350
YSI 600XLM (includes cables, software pH, ORP probes)	3	$13,000
HoBo Temperature Loggers	3	$250
Installation Hardware	3	$300
Calibration solutions (YSI)	pH, ORP, conductivity standards	$250
AA Batteries	Many (4 per YSI, changed every 30 days)	$175/yr
Van Doren bottom water sampler	1	$200
Sediment and water sample bottles	100	$200 (may be supplied by laboratory)
Hand Held YSI 85	1	$1,500 (possible rental)

EQUIPMENT	AMOUNT NEEDED	ESTIMATED PURCHASE COST
Secchi Disk	1	$60
Digital Scales (0-10,000 g)	1	$180
Square Enclosure	1	$120
100 m tape	1	$70
1m2 quadrat	1	$40
Color infrared imagery for vegetation mapping	Short-term: Once pre-restoration, Long-term: Every 5 to 10 years post-restoration	$5,000 per event
Analytical Balance	1	$4300
Benthic Corer	1	$40
1.0mm sieves	1	$200
Large beach seine	1	$250
Small beach seine	1	$140
Digital Scale (0.01g – 100g)	1	$220
Digital Scale (1.0g – 1000g)	1	$160
Spotting Scope	1	$300
Binoculars	1	$300
Boat/kayak, anchor, paddles	1	$350
Hip Waders	2	$200
Field Laptop or Palm Pilot	1	$1500
Digital Camera	1	$250

ANALYTICAL NEEDS			
CONSTITUENT	PRICE PER SAMPLE	PROJECT SAMPLE NEED/YR	ANNUAL COST
Nutrient analyses (water)	$100	28	$3240
Chlorophyll a analyses	$30	15	$450
Sediment grain size analyses	$100	24	$1200
Aerial Topography	$20,000; $10,000 for survey, and $5,000 for analysis of quantities	Immediate Pre-, Post Restoration; Every 5 to 10 years for the long-term for the data acquisition and analysis	$30,000 for both pre- and post-restoration images; $1,000 to $2,000 per year for the long-term
Nutrient analyses (sediments)	$60	24	$1400
Phytoplankton taxonomist	$100	12	$1200
Benthic sorting and taxonomy	$420	27	$11,340
Consumable lab chemicals/supplies/disposal	$8.50	64	$544

6.0 REFERENCES

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